EXPERIMENTS IN PHYSICS

HIGGINS

SIMPLE EXPERIMENTS IN PHYSICS

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PREFACE

The purpose of this manual is to teach some of the principles of physics that are commonly applied in things about us, and in such a way that the study shall be a training in observation and thinking. It may be used in courses where the important object is to afford such training, or in courses where its function is mainly to illustrate the subjects studied. To secure the first of these objects, the matter has been so arranged that the student shall have been prepared for each exercise by the work preceding it; and the exercise, drawing upon this knowledge, will add to it a single fact or principle by demonstrating its operation and by suggestive questioning. The same exercises may serve also the second purpose, and many of them show directly the application of principles in things about us.

In general, the material to be used is simple and not costly. Such material often serves best, because it divests the operation of strange or unusual features and directs the attention rather to the thing shown than to the method of showing it.

The manner of using this set of exercises may, of course, be adapted to the desires of the teacher and the facilities at hand. It is simply a set of demonstration exercises which, by their nature, their arrangement, and the questions incorporated with them, may serve to teach certain physical principles, to afford practice in study by observation

and interpretation of things and happenings; to give practice in the use of material and expressions of laboratory work in physics, and to teach the application of physical principles. The emphasis that may be put upon one or another of these ends will depend upon the object for which any particular course is being given.

SIMPLE EXPERIMENTS IN PHYSICS

MATTER

States of Matter

1. Collect various solid bodies, observe them, and note any physical fact that applies to all of them but is not true of liquids.

2. Pour a tumbler of water successively into various vessels. What change does the liquid body undergo each time? Think of other familiar liquids. Would they all act similarly? How would a gaseous body act under like treatment?

3. Blow through a tube into water in a glass. Have you any evidence that the gas (the "breath") is matter? What becomes of it after leaving the water?

4. Apply heat (a match flame) to the wick of a candle, carefully noting all that happens. Extinguish the candle flame and at once bring the match flame near the wick from above. The candle should become lighted when the flame is a half inch from the wick. What changes of state does the paraffin undergo before it burns?

Note. Many demonstrations of these changes may be made by using such common substances as wax, butter, sugar, lead, sulphur, soft solder, iodine, and ice; and gases from volatile liquids may be detected by their odors.

Properties of Matter

Impenetrability

5. Into the 2-hole stopper of a 4-ounce bottle fit a funnel tube; also a tube bent so as to open into water in a tumbler set beside the bottle. Arrange the apparatus as in Fig. 1. Pour water into the funnel and note the result. Account for what you observe.

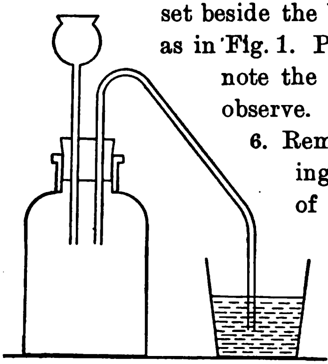


Fig. 1

6. Remove the bent tube (Ex. 5), closing the hole with a short piece of closed glass tubing. With the stopper tightly in place, pour water rapidly into the funnel. What do you observe? Loosen the stopper and note the effect. Account for what you see in both cases.

7. Push an empty tumbler, mouth downward, into water in a glass dish. Compare the surface level within the tumbler with that outside and account for it.

Note. Ex. 6 illustrates pouring thick liquids into closed vessels through small holes or funnels; the principle shown in Ex. 7 is applied in diving bells and in gas holders.

Hardening and Annealing

8. Try to scratch glass with the ragged end of a wire of *soft* iron. Now heat the wire end intensely and thrust it at once into cold water. Try to scratch the glass with this. Note any difference in the hardness of the iron.

9. Test a piece of watch spring for hardness and brittleness. Heat it intensely, cooling it *slowly* by lifting it gradually up through the flame and above. Again make the tests for hardness and brittleness and note any change.

Note. The principle of Ex. 8 is applied in the process of hardening and tempering iron; Ex. 9 illustrates annealing, a process used to toughen things that have been heated in fashioning, as glassware.

Cohesion and Adhesion

10. Hold two pieces of glass tubing end to end in a hot flame. When well softened push them together, holding and working them in the flame till they are well joined. What property of the molecules causes the pieces to unite?

11. Let fall drops of water, noting carefully their shape while falling. In a freely falling drop the effect of gravity (which would flatten a drop resting on a surface) is not felt. How do you account for the shape assumed by the drops?

To see this shape more clearly, place a drop of oil below the surface of water to which enough alcohol has been added so that the drop neither rises nor falls. Look at it from above, not through the curved glass of the dish.

12. Dip a clean glass stirring rod into water and lift it out. What evidence of cohesion do you see? What evidence that water and glass adhere?

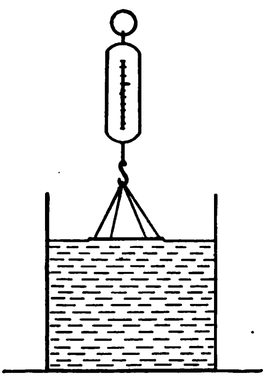


Fig. 2

13. Hang a piece of glass (4 inches square) by string from a sensitive spring balance so that it will lie horizontally. Note its weight. Lower the glass over water, taking care that all parts just touch the water surface and that there are no air bubbles between them (Fig. 2). Now lift the balance slowly, noting with care the greatest pull, as shown on the scale. From this latter reading subtract the weight of the glass. Show how this illustrates both cohesion and adhesion.

14. Cover a dry glass rod with a thin layer of grease or oil; dip this into water and remove it. Does water adhere to grease?

15. Fill a clean tumbler with water; then slowly pour out a little and note its manner of running out. Grease the rim of the tumbler for one fourth its extent and grease the outside of the glass below this part. Again fill and pour from the glass. What difference do you note? Explain it.

16. Press a bit of paper upon the dry surface of a tumbler. Wet the paper and repeat. State the results. What purpose did the water serve?

17. *Capillarity.* Half fill a clean tumbler with water. Closely observe the water surface where it meets the glass. What do you see? Account for it.

Hold a small glass tube vertically in the water. Compare the water level in the tube with that in the tumbler. What do you observe? Account for it.

Hold another tube, of smaller or larger bore than the one just used, in the water with it. Compare the water levels in the tubes. In which does the water rise higher?

Heat pieces of glass tubing in a flame and draw them out into capillary tubes. Use two or more of these tubes as you did the larger ones, noting the rise of water in them. What can you say in general about the rise of water in small tubes? To what force or forces is it due?

Examine a lamp wick and note its structure. Place one end of it in water in the bottom of a tumbler. Note the result after a few minutes and explain it.

18. *Surface tension.* Place a clean tumbler so that its rim will be in a level plane. Fill this with water, carefully adding more till its surface is well above the rim of the glass. Show how this result is due to cohesion. (Any particle within the water is pulled, so to speak, equally in all directions, there being molecules around it in every

direction. Each particle making up the surface has particles about it in every *inward* direction only, and is therefore pulled inward. Thus the whole surface of water is in a slightly different condition from other portions of the liquid.)

19. Cover a sewing needle with grease; then carefully lay it horizontally upon water. State and explain the result. (See Ex. 18.)

Thoroughly clean the needle, using soap and warm water, and repeat. Note carefully what the water surface does in each case. What part is played by the grease in keeping the needle up? (See Exs. 12, 14.)

NOTE. Ex. 10 illustrates welding of solids and Ex. 11 the method of making shot from molten lead. Ex. 16 shows the use of an adhesive agent, of which there are many, as glue, mucilage, paste, plaster, cements, etc. Ex. 17 shows the principle by which oil rises in wicks, water rises in the soil, ink spreads in a blotter, etc. Among the evidences of surface tension are the apparent floating of bits of various heavy substances and the movement of certain bugs upon water.

Elasticity

20. Measure a rubber band. Pull it to twice its length, let go, and measure it again. State the result. What property does this illustrate?

21. Use a spiral spring in the same manner, compressing instead of pulling it.

22. Cover a hard plane surface with chalk and drop upon it a smooth solid rubber ball, catching it upon the first rebound. Note the chalk mark upon the ball. What was done to the ball when it struck? Was its form permanently changed? Why?

Crystallization

23. Into a cupful of hot water stir saltpeter till the liquid will not dissolve any more. Pour off the *clear* solution into

a beaker and set it aside to cool. Crystals should soon appear, and their formation may be observed.

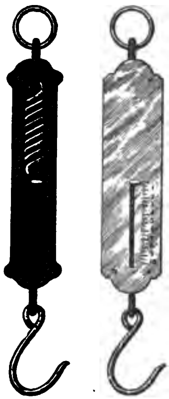


FIG. 3

24. Dissolve a little roll sulphur in carbon disulphide and pour the clear solution upon a watch glass. When the liquid has evaporated examine the residue for crystals. State any difference in the conditions under which crystals were formed in Exs. 23 and 24.

Gravity

25. Hold a book in your hand free from any support. Do you have to exert force to do this? Is any other force acting on the book at the same time? What evidence have you of this? In what direction do you act upon the book? In what direction does the other force act upon it? Name the other force.

26. Lift two convenient objects. Which of these weighs the more? Upon which is the effect of gravity the greater? What is meant by the "weight" of an object?

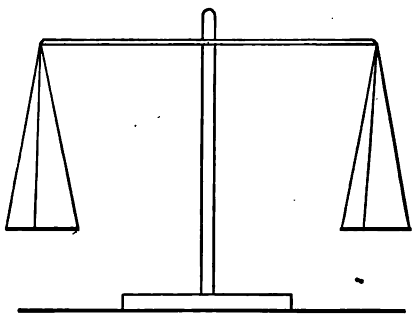


FIG. 4

27. Grasping a spiral spring by the ends, stretch it several times, using varying forces. What relation do you find between the degree of force used and the length of the spring? How could this be used for weighing things? (See Fig. 3.)

28. Weigh any object on common scales. (These may be easily made, Fig. 4.) Transpose object and weights. Do they still balance? State how we make use of gravity in weighing by this means.

29. Get one piece each of wood, glass, iron, cork, and lead. Lift these, and without any apparatus estimate their comparative densities. What factors do you consider in judging comparative densities?

Measurements

30. Make various linear measurements, using the metric units. Measure some of these objects in inches and compare the figures with the same measurement expressed in centimeters. What is the equivalent of 1 foot expressed in centimeters? Find the areas of several rectangular surfaces, using the metric units.

Note. The area of a parallelogram is the product of its base by its altitude. The area of a triangle is half the product of its base and altitude. The area of a circle is the product of the square of its radius by 3.14159.

31. Find the volume of a rectangular block, and also of a cylinder, using in both cases the metric units. In each case find the area of the base (Ex. 30) and multiply this by the altitude.

32. Using a graduate, measure 5 cc., 10 cc., 25 cc., etc., of water. Let the bottom of the concave surface (Ex. 17) come just to the required mark. Measure a test tube full of water. Measure an ounce of water; then measure again, using cubic centimeters. Estimate 5 cc. and 10 cc. in a test tube; then measure to see how closely you estimated. Repeat at other times till your estimate is fairly accurate.

33. Weigh various articles on common scales, using metric weights. Similarly use spring balances, aiming in both

cases to become familiar with the weights and also with the method of using the apparatus. How many grams make the equivalent of the avoirdupois ounce?

34. Upon one pan of sensitive scales place a clean, dry beaker, and balance it with weights upon the other pan. Carefully measure 10 cc. of water, pour this into the beaker, and note how much you have to add to the other side to make the true balance now. Note this result. Dry the beaker, balance it as before, and repeat the operation several times, using various quantities of water. Compare results and make an inference regarding the weight of 1 cc. of water. Results may not perfectly agree, but they may be made very accurate with care.

FLUID PRESSURE

Pressure in Fluids Independent of Direction

35. With a small wire nail make a hole in the bottom of a tin can, and another in its side as near the bottom as possible. Plug the latter; then fill the can with water and note the flow.

Now plug the bottom hole, removing the side plug; refill the can and note the flow of water.

Empty the can, open the bottom hole, and plug that on the side. Thrust the empty can, bottom downward, into water in a deep dish, and look in the can to note the flow. In what directions does this fluid body exert force?

36. Cover the end of a lamp chimney with a piece of cardboard and thrust that end down into water in a glass dish. Move this about in the water. Is the card held firmly to the glass? What holds it there? Now pour water into the chimney till it rises to a level with the water surface outside. The card being thin, its upper and lower surfaces are practically at the same depth. Move the chimney a little. Is the card now held firmly to the glass? Compare the pressures upon its upper and lower surfaces when these are at equal depths.

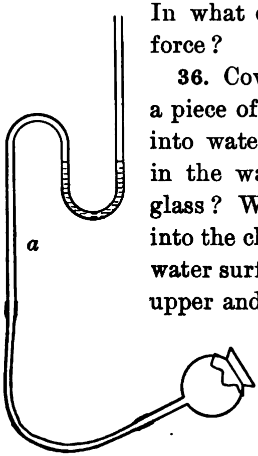


Fig. 5

37. Bend a long piece of tubing to the shape of *a*, Fig. 5, and put water in the bend to serve as a pressure gauge.

Tie a piece of thin rubber so as to close the mouth of a thistle tube completely, and connect this thistle tube with the gauge by a rubber tube. (Cut off the straight tube near the funnel end.) Now move the funnel about in water so that its surface may be turned in various directions, being careful that the center of this surface is always at exactly the same depth. Note the height of water in the gauge while you are doing this. Does the change of direction alter the pressure upon the rubber surface while its average depth is constant?

Effect of Gravity upon Liquids

Liquid Pressure

38. Pour water downward through a long thistle tube. What causes it to run as it does? Does anything oppose its running through the tube?

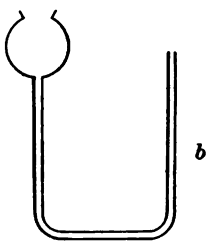


Fig. 6

39. Bend a funnel tube as in Fig. 6 and pour a little water into it. Compare the final liquid levels in both arms of the tube. State fully how the water got to this level in the arm *b*, giving the principles illustrated by its action.

40. Fit a 1-hole stopper into a student-lamp chimney and a short glass tube into the stopper. Connect this bit of tube with a 12-inch piece (straight) by a long rubber tube. Hold the chimney and glass tube vertically in one hand and pour water into the chimney till it can be seen in the glass tube. Pinch the rubber to get out all air bubbles. Now hold the glass tube at various distances from the chimney and note the surface levels in the two. How do they compare? Does the fact that one

body of water is much larger than the other make any difference in this result? What raises the water into the glass tube?

Note. **This illustrates gravity water-supply systems, the chimney representing the reservoir or standpipe and the tube the distributing pipes in buildings.**

Relation of Pressure to Depth

41. With a small wire nail make three holes in the side of a tall tin box, — one near the bottom, one an inch from the top, and one between these. Plug the holes. Fill the box with water and (one at a time) let the water flow from each hole, filling the box for each separate trial. Note the energy of the flow at each of the three depths. Assuming the energy of the flow to be a gauge of the liquid pressure at each hole, what can you say of the relation between depth and liquid pressure due to gravity?

42. Use the pressure gauge made for Ex. 37, pushing it downward into water to various depths and noting the gauge meanwhile. What do the results show?

43. Use the device of Ex. 40, substituting for the long glass tube a short tube drawn to a jet. Fill the chimney with water. Hold the chimney in one hand and the jet pointed upward in the other. Vary the vertical distance from the water surface in the chimney to the jet, noting the corresponding flow from the jet. Upon what does the liquid pressure at the jet depend?

Note. **This may illustrate fountains and the "head" of water from a reservoir.**

Principle of Archimedes

44. By means of a string lower a stone into water. Does it seem lighter or heavier when immersed? Why? Is it really different in weight?

45. Repeat Ex. 44, noting the water surface as the stone is being lowered into the liquid. (Use a glass vessel not much larger than the stone.) What do you see? What does this show in explanation of the buoyant effect upon the stone?

46. Get a 2-inch piece of gas pipe that will fit into a small graduated cylinder. Weigh the metal in air and again in water. Write the buoyant effect of the water upon it (in grams). Put water into the graduate, carefully noting the mark to which it rises. Lower the metal into this and write the volume of water it displaces (in cubic centimeters). How much does this displaced water weigh? (See Ex. 34.) How does the buoyant effect upon the immersed body compare with the weight of the liquid it displaces?

Floating Bodies

47. Place a block of wood upon water. What happens to it? What forces are acting upon it, and in what directions (while it is at rest on the surface)? Compare the effects of these forces upon the block.

48. Place pieces of soft wood, cork, and Ivory soap upon water. State the proportionate depth to which each sinks. What relation do you discover between the specific weight of the substance and the proportionate depth to which it sinks?

49. Get a small stick of wood that will fit closely into a graduated cylinder. Put into the graduate enough water to float the stick. Weigh the dry stick, writing this in grams. Put the stick into the graduate and note the displacement of water. Write this in cubic centimeters and also state the weight of this volume of water. Compare the weight of the floating body with that of the liquid it displaces.

50. Lay a tumbler on its side in water, let it go, and state the result. Now place in the tumbler enough shot or

water so that you can place it upright in the water without its sinking. Why should it sink in the first case and not in the second?

NOTE. This shows why vessels of iron or steel, can buoys, and other metallic objects may be made to float upon water.

SPECIFIC GRAVITY: METHODS

Heavy Solids

51. Fasten a light piece of string to a piece of iron and weigh the iron. Weigh a dry saucer. Place a tumbler in this saucer, where its rim will be level, and fill it with water till another bit would overflow it. (Several trials may be necessary.) Now immerse the iron, taking care that the overflow shall be as nearly as possible the same in volume as the iron. Remove the iron and then carefully remove the tumbler, getting the water from its outside into the saucer. Weigh the saucer and contents. From this subtract that of the saucer alone. The result shows the weight of how much water? Compute the specific gravity of the iron. What sources of error are present in this method?

52. Weigh a dry piece of iron, and again weigh it in water. Subtract the second weight from the first and state what the apparent loss of weight represents. (See Ex. 46.) Compute the specific gravity of the iron. Is this method more or less accurate than that of Ex. 51? Why?

Other substances should be used in the same way, e.g. stone, glass, lead.

Solids Lighter than Water

53. Suspend a block of soft wood from a scale by a light string and record its weight. Below the block fasten a small stone that is heavy enough to sink the wood. Now let the block hang so that it is dry, but with the stone immersed

in water (Fig. 7), and record this weight as *w*. Again, lower the whole till the block also is immersed, both hanging free. Record the weight shown now and call it *w'*. Since the stone is weighed immersed both times, its effect may be neglected, and the difference between *w* and *w'* will be the true measure of the buoyant effect upon the wood. Subtract *w'* from *w* and state what you have virtually weighed. You now have the weight of the wooden block and that of an equal volume of water; compute the specific gravity of the wood.

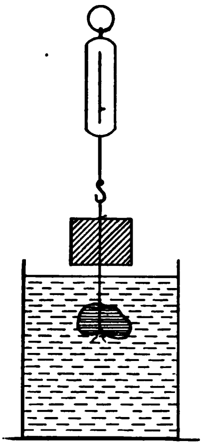


FIG. 7

54. Cut small sticks of any light and any heavy wood, about 4 inches long. Place one of each in an 8-inch test tube with water enough to float them. Note the proportionate amount of each that is beneath the water and state which is specifically the heavier. How do you judge?

(For light woods, spruce, white pine, poplar, butternut, or willow will do; for heavy woods, ash, white oak, witch-hazel, box, hard maple, or lignum-vitæ. Try the exercise without knowing what kinds of woods are being used.)

Liquids

55. Weigh a solid lump of glass in air. Now weigh it immersed in water, recording the apparent loss of weight. Again, weigh it in any other liquid, as alcohol, glycerin, or some salt solution, and record its seeming loss of weight in that. From these figures and the results of Ex. 46 compute the specific gravity of the second liquid.

56. Into a 6-inch test tube put shot enough so that it will float with a little more than half its length under water.

With a file scratch a mark to show where the water surface stands on the glass. In a denser liquid would this test tube sink more or less than it does in the water? Why? Put it into alcohol, and again into a strong salt solution, and verify your answer.

57. Throw two or three BB lead shot into mercury in a small dish. The specific gravity of lead is 11.4. What can you say, from this exercise, about the specific gravity of mercury?

PASCAL'S PRINCIPLE: THE HYDRAULIC PRESS

58. Cut a small hole in the side of a shallow tin dish, and into this solder a short tin tube (Fig. 8). To the tube fasten a long rubber tube, and insert a funnel tube into the other end of this. Tie a cover of sheet rubber very securely over the dish, as in the figure. Fill the whole with water up to the funnel. Place some large books upon the rubber cover and lift the tube to a sufficient height so that these books will be raised. Upon what will the pressure of the liquid upon the rubber depend? Upon what will the total force of the water against that surface depend? Knowing the pressure per square inch upon the rubber sheet, how could you find the total force exerted upward upon the books?

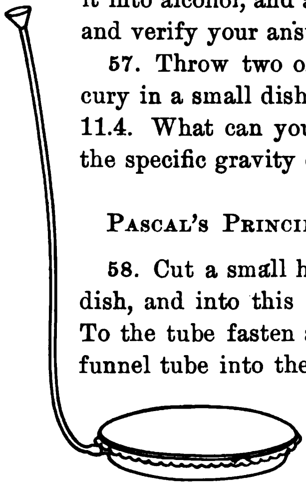


FIG. 8

What could be done to this device to make it serve as an hydraulic press?

NOTE. Hydraulic presses must be made very strong to withstand the pressure that they put upon the water in themselves. They are used for pressing cotton, hay, etc., into bales, squeezing juice from fruits, etc., pressing books when newly made, cutting and forming iron and steel, and as "jacks" the principle is applied in lifting heavy things.

Atmospheric Pressure

Effect upon Solids

59. To the center of a circular piece of harness leather, 4 inches across, fasten a stout string. Soak the leather some hours. Place it, dripping wet, upon a smooth surface, and crowd it down well to exclude the air from beneath it. Pull up on the string. State the result and account for it.

60. Open a paper bag by blowing it full and then removing it from the lips. What is now true of the pressures upon the paper, without and within?

With the bag at the lips, withdraw some air. What change does this make in the pressure within the bag? What happens to the bag? Is this due to a pull from within or to a push from without? Explain fully.

Atmospheric Effect upon Liquids

61. Use a 6-inch piece of glass tubing, about 6 mm. in diameter, open at both ends. Thrust one end into water, close the other end tightly with the finger, and lift it out. What do you see? What holds the water in the tube? Are the pressures upon the upper and lower surfaces of the water in the tube equal?

To help in answering the last question, lift the finger that closes the tube. What is now true of the pressures upon the upper and lower water surfaces (at the instant the finger is raised)? What happens to the water under this condition?

Again, get water in the tube and close it with the finger. If the pressures on the water surfaces are unequal, which is the greater? Which has changed? What caused this change?

This exercise is worth thoughtful study. The student who works out its explanation does well.

62. Fill a tumbler with water. Cover this with a piece of cardboard a little larger than the mouth of the glass.

Hold the card in place, invert the tumbler, and remove the hand from the card (Fig. 9). What do you see? Account for it. What purpose does the cardboard serve?

FIG. 9

Holding the whole over some large dish, grasp the card by one corner and suddenly pull it sidewise away from the glass, carefully watching the water. As the water goes out, what else happens that is essential? In Ex. 61 what served the purpose that the cardboard does in this exercise? (See Ex. 18.)

63. Put water in a small machine-oil can, screw the nose on, and then invert the can. Does the water run out? If not, what holds it in? What is true of the air pressure on the water from within the can?

Punch a small hole in the bottom of the can and repeat the exercise. What do you notice now? What was the direct result of making a hole in the can above the water? What makes the water run out? Close the hole tightly with your finger and note the result.

NOTE. In small tubes the surface of the water is strong enough to withstand the slight push of the air upon it, so that no card is needed. This is true of the surface of oil in a small-nosed oil can. Ex. 63 also illustrates the use of "vents" in any vessels from which liquids are drawn by gravity through small openings. In pouring from bottles, the liquid leaves, and the air enters, by the same opening.

Transmission of Atmospheric Pressure by Liquids

64. Fill a tumbler under water in a large dish, invert it, and slowly lift it till only its rim remains below the surface. What do you see? What is the cause of this? What purpose is served by the liquid in the dish outside the tumbler?

Repeat this with a test tube, or, better, with a long tube closed at one end. Could such a water column be so high that the atmosphere would not hold up the whole of it?

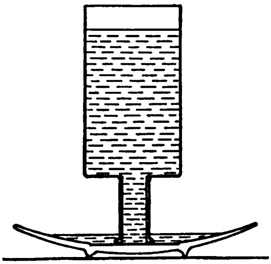


Fig. 10

65. Fill a small-mouthed bottle with water. Cover this with a deep saucer, inverted. Holding the saucer in place, invert the whole so that the saucer shall rest upon a table and the bottle be inverted upon it (Fig. 10). Fully state what occurs with reference to the water. Account for it. Now lift the bottle so that its rim shall be off the bottom of the saucer without being above the water surface at any point. Holding it there, withdraw water from the saucer by means of a tube till something else is noticed. What do you presently see? Where is the water surface in the saucer at that moment? What happens immediately after? Make a full explanation of all that you observe.

(This is more effective if, in place of the bottle, a tumbler is used, in the rim of which a notch has been filed three eighths of an inch deep. Use a round file and hold the glass under water while filing.)

Note. This principle is important wherever liquids are raised through pipes by pressure upon a free liquid surface, as in wells or in "sucking" liquids through tubes. Ex. 65 illustrates the action of certain ink wells, chicken fountains, and holders for dispensing drinking water, etc.

Pumps

66. Thrust one end of a long open glass tube into water. With the other end at the lips, withdraw some of the air from the tube. What effect has this upon the pressure of the air left in the tube? What happens then? Why? Note the principles previously learned that are applied in this exercise.

67. Use a 6-inch piece of glass tubing. About one end of a stout wire wind cotton twine till it will just fit within the tube. Push this end through to the far end of the tube and put the latter in water. Pull the wire up through the tube. How does this affect the pressure upon the water surface within the tube? What follows as a result of this? What raises the water? Water can be lifted by this device; what more is needed to make of it a lifting pump?

68. Into a large glass tube fit a piston having a valve that will open upward when the tube is placed in water for use. For a tube, a student-lamp chimney will do, if its smaller end is not of less diameter than the main cylinder; look over several till one is found. For the piston, wind cotton twine around a common spool till it fits the tube. In one end of this fasten two screw eyes, one on either side of the hole. Between these, covering the hole, fasten a piece of thin leather by one tack so that it will form a hinge valve. Bend a stout wire through the screw eyes and form it into a handle for the piston. Put the piston in the tube, soak it, and then operate it as a pump. Lacking a valve to hold the water in check, hold the tube firmly to the bottom of the vessel during the downstrokes and tip it a bit on the upstrokes. Describe and explain its action.

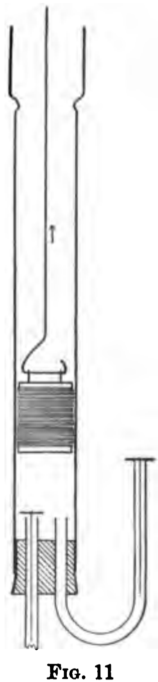


FIG. 11

69. *Force pump.* Fit a 2-hole stopper into the tube (Ex. 68). Remove it. Into one hole fit a straight glass tube and into the other a U-shaped tube, both to open outward from the big tube. (See Fig. 11.) Cut a bit of leather twice the diameter of the small tubes, run through its center a long, straight wire, and cover the inner opening

of the straight tube with it, the wire hanging down inside the tube. Cover the outer end of the U-tube with a like valve. Make a plunger like the piston in Ex. 68, but make no valve, and plug the hole so that it is solid. Put the plunger into the tube, then put the stopper in place. Soak the plunger and valves. What part does atmospheric pressure play in the force pump? What can be done with a force pump that cannot be done with a lifting pump?

NOTE. Ex. 66 has many common applications; Ex. 67 illustrates the common piston syringe; Ex. 68 illustrates the pump used to lift water from wells to houses, to pump out ditches and boats, etc.; and the force pump is used with windmills for pumping to high tanks, and also with steam fire engines, city water systems, and in various ways where liquids have to be lifted to considerable heights or driven under some pressure.

Siphon

70. Fill a U-shaped tube with water, close one end with the finger, and invert it. Before removing the finger place one end in a tumbler full of water and the other in an empty tumbler. What do you see? When does the water stop flowing?

Now, without disturbing the tube, lift the second tumbler till its water surface is above that in the first. What now happens? Repeat in various ways, lifting first one and then the other glass. In every case, when the water is flowing, compare the vertical distances from the top of the bent tube to the water surfaces in the tumblers. What is true in every case?

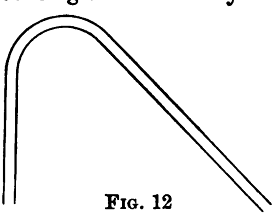


FIG. 12

71. Bend a tube at an acute angle, making one arm twice as long as the other. Fill this with water, covering one end. Hold it as in Fig. 12, both ends being *exactly* on the same level. Release the closed end and state the result.

Now refill and tip the tube so that the long arm will open at a lower level than the short arm, and then remove the finger. State the result.

Once again fill the tube, close one end, and hold it so that the short arm will open lower than the long arm; then release. Out of which arm does the water now run? Upon what does the direction of the flow depend? (See Ex. 41.) What causes the liquid to flow?

72. Fill the tube used in Ex. 71, cover one end, and place the other end in a tumbler of water. Look at it and determine in which way the liquid will probably flow; then remove the finger. Upon what did you base your judgment? As the water flows out of the tube, what flows in? What forces it?

73. Nearly fill a large bottle having a small mouth. Into the liquid lower a long rubber tube till there is more than enough to reach the bottom. To what point in the tube has the water now risen? Pinch the tube tightly together and gently pull it out of the bottle till the point in the tube to which the water had come can be brought lower (outside) than the level of the water in the bottle. Then release the tube. Several trials may be needed before you can correctly estimate. Over how great a height (above the liquid surface) could water be raised by a siphon?

NOTE. The siphon has many applications. It affords a convenient way to fill small bottles, etc., from large receivers that cannot be easily poured from. The plumbing in an ordinary house includes several siphons as a rule. The "traps" in drainpipes are commonly siphons.

Barometer

74. Into a small cup pour mercury to the depth of one inch. Close one end of a glass tube 32 inches long. Fill this tube completely with mercury and cover its open end tightly with the finger. Is there now any air in the tube? Now invert the tube, thrusting the end beneath the surface

of the mercury in the cup, taking great care not to let the least bit of mercury out, or air in, till the end is well covered by the liquid. Then remove the finger, noting the result on the mercury column. What do you see? What is now in the tube above the mercury? Could the atmosphere, now and here, hold up a higher column of mercury? As the atmospheric pressure changes, what will happen to this column? Measure the column from the liquid surface in the cup to the top of the column in the tube. Record the height.

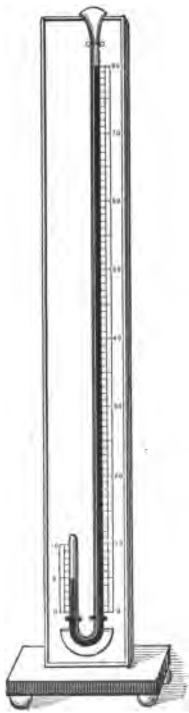


FIG. 13

NOTE. The barometer is designed to measure the pressure of the atmosphere. Thus it comes to be useful in such related matters as forecasting weather changes and measuring altitudes.

OTHER NOTES ON GAS PRESSURES

Boyle's Law

75. Fig. 13 shows a "Boyle's Law tube." It is of uniform bore, with the short arm closed and the long arm open. Attach it to a support so that it will be vertical, and fasten metric rules beside it, as indicated. Pour mercury into the tube till it stands at the same level (0) in both arms. The volume of gas (air) inclosed in the short arm is now subjected to a pressure of one atmosphere. Measure the length of this air column (i.e. from the mercury surface to the closed end of the tube) and express it in centimeters. Now pour mercury into the tube till the vertical distance from one liquid surface to the other is equal to the present height of the barometer column (Ex. 74). This

adds one atmosphere to the pressure upon the gas inclosed in the short arm. Again measure the length of this inclosed body of air, and record it.

The tube being of uniform bore, the volume of the gas inclosed in the short arm will vary as its length varies; hence the measured lengths recorded above show the relation of the two volumes of gas — under a pressure of one atmosphere, and then of two atmospheres. State the relation between the volume of the gas and the pressure upon it.

Compressed Air

76. Remove the pith from a straight stick of elder 10 inches long and 1 inch thick. Make a stout ramrod a bit smaller than the hole. Into one end of this popgun fit a stopper as in a bottle. Into the other end insert a cork completely, first greasing it well. With the rod push this latter cork quickly through the tube towards the first. What happens? What was done to the air that filled the tube at the start?

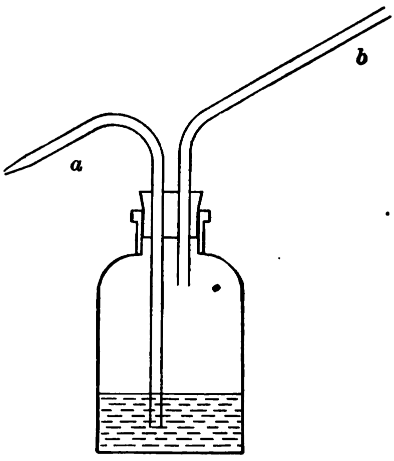


Fig. 14

77. Fit two tubes, *a* and *b*, into the 2-hole stopper of a 4-ounce bottle. Bend and adjust these as in Fig. 14. Put water in the bottles as the figure indicates. Blow into *b*. State the result and account for it.

78. Get a bottle of at least 8-ounce size and a 1-hole stopper to fit it. Cut a straight tube long enough to reach

the bottom of the bottle and protrude an inch or more from the stopper. Draw the outer end of this to a fine jet. Arrange these, with a little water in the bottle, as in Fig. 15. Now blow into the jet just as much air as you can, having the stopper tightly set and filling the lungs well. When you can blow no more, quickly draw the jet from the mouth and hold it away from your face. Explain the result.

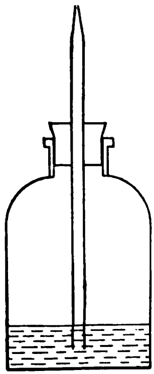


Fig. 15

79. Examine a common hand pump for bicycle tires. Operate it; then tightly close the end with the finger and again try to operate it. What is the result? Examine the valves, or the piston if it has no valves. Where does air enter the pump? Why does it not go out the same way?

Note. Various other devices may illustrate the use of compressed air. The uses are many. It runs engines, lifts water and oil from deep wells, runs pneumatic drills and hammers, cash and mail delivery tubes, helps build tunnels by driving a shield through the earth, serves as a shock absorber in tires, cushions, and door-closing devices, and drives blasts of air into furnaces, to divers, and to various places for various uses.

MOTION AND FORCES

Newton's Laws of Motion

First Law: Inertia

80. To a weight of about 5 pounds fasten a cotton string about 3 feet long. Holding the string by its free end, let the weight hang suspended. What force do you balance in doing this? Now try to lift the weight by a sudden and violent pull upon the string. What do you now fail to overcome?

81. Fix a hammer head loosely upon its handle. Hold this by the handle, head downward, and strike a sharp blow upon the end of the handle, using another hammer or a stone. What is the result as regards the hammer head? Account for it, using the first law of motion.

82. Throw a ball. What force moves it? Through how much of its course does this force act? Does any other force act to keep it going? Why does it continue to move?

83. Wet a whisk broom and snap it, as is commonly done to get the water out. Explain how the first law of motion is applied here.

84. Mark a certain spot upon the floor (lay down a bit of paper). Standing at this place, toss a light ball (yarn or hollow rubber) *vertically* upward. Immediately walk briskly forward. Where does the ball fall with reference to yourself?

Now start 10 feet away from this spot, walk briskly towards and past it, and as you pass the spot toss the ball vertically upward again. Where does it come down this

time? Explain the results as regards the motion of the ball in both cases.

85. Roll a ball along a horizontal surface so that it may stop seemingly "of itself." Does gravity oppose a perfectly horizontal motion? Look closely and see if this motion is perfectly horizontal. What do you see? With this in mind, what force can you say stops the ball, and how?

86. Throw a very light ball (e.g. a wad of tissue paper) as forcibly as you can with ease. Does it go as far as a heavier one would go? What force opposes its motion? Would this force tend to stop other things moving through the air?

87. Hold a ball in the hand at rest. Suddenly move the hand out from under it. What happens to the ball? Does it start to move "of itself"?

Lay the ball, at rest, on a sloping table or board and remove the hand. Does the ball move? Does it place itself in motion? What force moves it?

NOTE. These exercises illustrate that bodies at rest tend to remain at rest (Exs. 80, 81); that when in motion a body tends to keep moving (82–84); and that things which seem to stop (Exs. 85, 86) or to start (87) "of themselves" are really acted upon by forces, though they may not at first thought seem to be. In picking up things on a shovel or scoop, in pulling a book or box from beneath a pile, in the effect upon us when a car suddenly starts with violence, we see evidence that bodies tend to stay at rest. In all projectiles, in shaking rugs or in shaking salt from a sifter, in throwing coal or sand from a shovel, or in any moving body at all, we may see the tendency of things to stay in motion.

Second Law: Action of Forces

88. Lay a ball on the table. Strike it two equal blows at the same instant in opposite directions. What is their effect upon the ball?

Fasten two screw eyes in opposite faces of a small block of wood. Into these hook spring balances and pull on the

block in opposite directions with exactly equal forces, as shown by the scales. What is the effect of two equal forces acting in opposite directions at the same time?

89. Fasten screw eyes into a block of wood, as in Fig. 16, making *c* and *d* equally far from *b*, and *e* twice as far. Hook a spring balance into *a* and fasten it at a point *o*. Hook balances into *c* and *d*. Pull upon *c* and *d* in directions exactly parallel to the line *oa*, and with such forces that the long axis of the block is kept at right angles to *oa*. Read the scales of each balance and record the pulls. Compare those at *c* and *d* with each other. Add them and compare the sum with the pull at *a*. State the results and make conclusions.

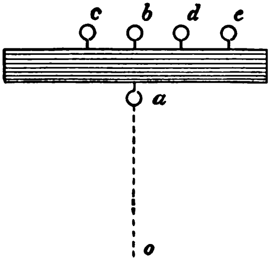


Fig. 16

90. Repeat Ex. 89, only with one scale hooked at *e* instead of at *d*. Have the others at *c* and at *a*, and pull as before, always keeping the block perpendicular to *oa*. Note the readings of the scales. Compare the pull at *c* with that at *e*. Compare the distance *bc* with *be*. From these comparisons make an inference concerning the relation between a force tending to produce rotation and the distance of its point of application from the center.

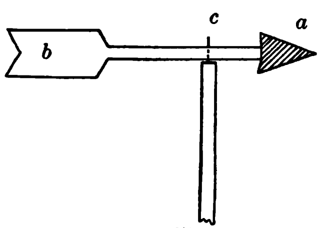


Fig. 17

91. Make a weathervane like that in Fig. 17. Weight the head end by wrapping it with lead foil till the whole is balanced and turns freely upon its pivot at *c*. Blow upon this (better, place it in the wind, whose effect you can hardly duplicate). Which

side, *a* or *b*, receives the greater force of the wind? Why? Which end moves with the wind? Does the arrow point in the direction from which, or toward which, the wind blows?

92. Lay a ball on a level surface and strike it two equal blows, at the same instant, at right angles to each other. Note the direction in which the ball moves. Does each force have an effect on the motion of the ball?

93. Upon a narrow block of wood fasten a stick (Fig. 18) 5 inches long by a screw ½ inch from one end, upon which it may turn freely. Drive a wire nail at *n* to stop the stick

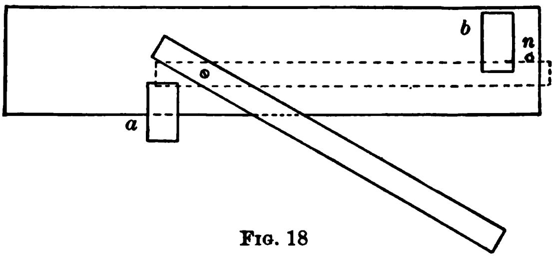


FIG. 18

as it shall be snapped from such a position as the figure shows. Place blocks of wood, *a* and *b*, so that the moving stick will hit *b* a sharp blow and at the same instant gently push *a* over the edge. The object is to project *b* some distance, while *a* simply falls directly downward, both starting at the same time. With the blocks and the stick in position, as in Fig. 18, hold the whole with its upper face exactly horizontal, and then with the finger snap the stick towards *n*. Listen for the sound of the blocks striking the floor. Repeat several times and allow for the possible error in holding the block horizontally. Do the blocks fall through the same vertical distances in the same time? Is the effect of gravity upon *b* affected by the other (the projecting) force that acted upon it at the same time?

94. Make a loop in the end of each of three pieces of stout string. Tie the other (free) ends together, as at *a*, Fig. 19. Hook spring balances into these loops (one in each) and fasten the ring of one spring balance at any point, *o*. Now pull upon the other two with any such intensities, and in any such directions, *b* and *c*, that the point *a* shall not move as a result of the pulls upon it. At this moment slip a paper under the strings and accurately mark their directions away from *a*. Note also, with care, the readings of the scales at this moment, recording the number of grams upon each corresponding line.

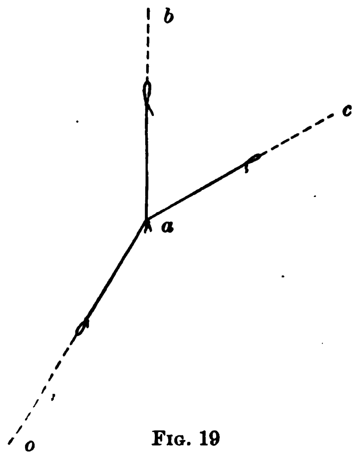


FIG. 19

Now draw upon the paper the lines whose directions have been indicated. Upon each line, beginning at *a*, measure a distance (*ao*, *ab*, *ac*) which shall correspond in units to the number of units of force in that direction. Now upon *ab* and *ac* as sides construct a parallelogram. Draw its diagonal. How does this diagonal compare in direction and length (intensity) with *ao*? Explain.

95. Make a small windmill of wood with blades set obliquely (as in windmills). Blow upon this from directly in front. How does the direction of its motion compare with that in which the force (the wind) acts? Explain why it moves as it does. Why not make windmills with blades set perpendicularly to the plane of its motion, to be blown upon from one side?

NOTE. We see very few motions that are not the result of two or more forces acting; thus these principles are commonly exemplified.

We may simply call attention to such matters as the propulsion of sailing vessels, the use of rudders in boats and air craft, steering in skating, coasting, and the like, as notable cases where two or more forces cause bodies to move in directions different from those of either of the forces.

Third Law: Reaction

96. Strike the table with the hand. In what direction do you act upon it? Is there also a force exerted against your hand at the same moment? In what direction? What evidence have you of this reaction?

Again strike the table more forcibly. Does the reaction also seem to be more forcible? Upon what does the intensity of any reaction depend?

97. Bend a 3-inch piece of glass tubing in a right angle, 1 inch from one end. Fit the other end into a piece of rubber tubing 1 foot or more in length. Let this hang free, glass tube down, and blow violently into the upper end. What is the result? What, in this case, constitutes the action and what the reaction?

98. Take two 8-inch glass tubes and draw one end of each to a jet. Bend one tube to a right angle, 1 inch from the jet; then, 2 inches from the other end, bend it to a right angle in a plane perpendicular to that of the first. Make the other tube exactly like this one. Fit the larger end of each tube into a 2-hole stopper, the tubes directed outward and in opposite directions from each other. Fit the stopper into a student-lamp chimney and suspend the chimney by string so that it shall hang vertically, stopper downward, and be free to rotate. With the chimney at rest, pour water into it. Explain the result.

99. Make a model screw propeller of wood, "tin," or cardboard. Study this till you understand clearly how it acts upon the air in turning, and how the reaction of the air would affect it. Explain how it would work in driving a boat or an airship.

100. Strike the table with your fist as forcibly as is comfortable; then strike a pillow or cushion with equal force. Could you comfortably strike the cushion more forcibly? State a good reason for the difference.

101. Reflected motion is due in part to reactions. Set up a board firmly so that its face is in a vertical plane. Roll a ball towards it so that it will strike exactly at right angles with the face of the board. Note how it leaves the board. Roll it toward the same spot several times, varying the angles that it makes with the board in striking. In every case note the angle it makes in leaving. Make a general statement, comparing the angle at which the ball strikes with the angle at which it leaves the board.

NOTE. Applications of the third law are numerous, and many are useful. The forces that stop most moving bodies are reactions against their own action: Ex. 97 shows how hose, especially fire hose, "kicks"; Ex. 98 illustrates some lawn sprinklers and automatic fire extinguishers; Ex. 99 illustrates the principle of propellers, of screws, and of electric fans; and Ex. 100 suggests how all sorts of cushions and springs serve to lessen the severity of reactions by distributing them. These are intended simply to suggest the variety of applications of this law.

MOMENTUM

102. Let one student stop a ball that another rolls, first slowly and then with some speed. Which is more easily stopped? Which has the greater momentum? What is one factor in determining the momentum of a body?

103. Perform Ex. 102, but use two balls, one heavy and one light, and roll both at just the same speed. Which has the greater momentum? Name a second factor in determining momentum.

104. Cut a circle 4 inches in diameter of stiff cardboard. Through the center make a hole upon which the card may turn very easily about a wire nail. Make for it a rim of

heavy metal, such as a ring of $\frac{1}{4}$-inch lead wire, but do not attach it. Holding the card upon the nail as an axle, spin it as forcibly as you can with a single effort, and note how long it runs. At once fasten the rim in place, using sticky papers (gummed labels). Again spin the card as forcibly as before, noting how long it now runs. State the results and account for what you notice.

NOTE. Ex. 104 illustrates the use of momentum as applied in fly wheels. These are used in engines and in some machines to continue motion during brief intervals when no force is applied, and to make motions steady. Momentum is depended upon in firing projectiles and in switching cars, and illustrations of it are as common as motion itself.

CENTER OF GRAVITY

105. Cut an irregular piece of cardboard. Fasten a small weight upon a string. Thrust a pin through the card at a point (*a*, Fig. 20) near the edge. Around this pin make two or three turns of the string so that the card and stone may both hang freely, as shown in Fig. 20. Grasp the card and string so as to trace the direction of the latter across the card. Now repeat this, using other points, *b* and *c*. Do these lines intersect? Try to balance the card on your finger placed at the point of intersection. Disregarding the thickness of the card, what point have you approximately located?

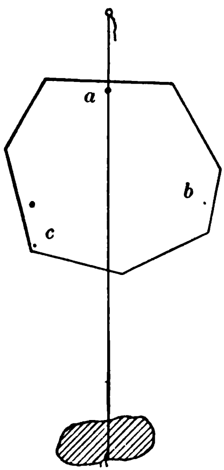


FIG. 20

106. Cut a 4-inch circular cardboard. Balance this on the finger tip and mark its c.g. Now fasten a penny to the card by a sticky paper, near one edge. Again locate the center of gravity. How has its position changed? What brought about this change?

While the coin is attached, run a wire nail through the center of the card and whirl the card upon this. Again, make a hole at the c.g. and whirl the card about the nail run through this. Note any difference in the motion of the card in both cases. Which time does it run more smoothly? What could you do (without removing the coin) to make this run smoothly upon the nail through its center?

107. Balance a ruler on the finger and mark its center of gravity. Now lay it on the table and push one end slowly over the edge till it falls. At the moment of falling, where is its c.g. with reference to the table? Repeat, using other objects, the position of whose centers of gravity may be readily determined. Under what part of a body must a support be placed in order to serve its purpose?

108. Find the c.g. of a cardboard by balancing it. Mark this spot. An inch to one side of this make a small hole and suspend the card so that it will turn easily about a nail or pin through this hole. Let it hang freely on a support through this hole. What position does its c.g. assume? Disturb the card slightly. Does this raise or lower the c.g.? When you let go, what position does the c.g. of the card take as it comes to rest?

109. Try to balance an egg upon one end. What happens whenever you let it go? Account for this.

110. Get a half sphere of lead and fasten to it a cylinder of paper, making it fairly long, but not enough to make the c.g. fall outside the lead hemisphere. (See Fig. 21.) This object, placed upon its side, will seem to rise to a vertical position. Draw a diagram showing its c.g. when the object is horizontal and when it is vertical, and explain its action. When a body is free to move, what position does its center of gravity assume?

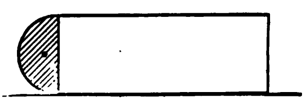


FIG. 21

111. Watch the fall of an irregular body from a height. Describe its motion in falling. Does every point in the body fall in a straight line? Does any point fall in a straight line? If so, what point is it?

NOTE. **Ex. 106 illustrates the use of counterpoises in fly wheels of engines and in other revolving parts of machines.**

Equilibrium

112. Use the cardboard of Ex. 108. When it hangs freely from its support (the nail) in what state of equilibrium is it?

113. Place a long pencil upon its end on a table. In what condition of equilibrium is it?

114. Lay a ball on the table and note its condition of equilibrium.

115. Place a wooden cone on the table, upon its base, then upon its side, and finally balanced upon its apex. In each case state its condition of equilibrium.

116. Try to balance an egg on its end upon a flat surface. If you could do so, in what state of equilibrium would it be? The egg rolls over and comes to rest. In what state of equilibrium is it with regard to a rolling motion? What state is it in with regard to a rocking motion?

Stability

117. Make a low pile of blocks and test its stability. Do this by lifting one edge of the bottom block slowly till the pile falls over. Note the angle between the face of the block and the table at this moment. Double the height of the pile and test its stability in the same way. Which is more stable? What factor in stability has been changed by adding the blocks?

118. Get a uniform 6-inch stick of wood about 1 inch square. To one end of this fasten a cardboard 2 inches

square (Fig. 22). Find the c.g. of the object. Is it much nearer one end than the other? (If it is, use a different stick.) Now place the object first upon one end and then upon the other, testing its stability each time. What factor in stability has here been changed?

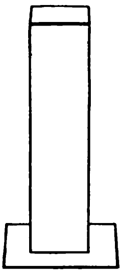


Fig. 22

119. Place a ruler on the table upon its side, and then upright on one end. In which case is it more stable? Why?

120. Fasten the blade of a jackknife into a pencil about 1 inch from the point, and adjust its handle so that it will lie about parallel with the pencil and extend beyond the point. Balance the whole upon the pencil point, this being placed near the edge of a table so that the knife handle may hang freely off the table. Where is the c.g. of the object with reference to its point of support? What is true of the stability of bodies that are so supported?

121. Make a tripod with legs that can be adjusted to give it a small or a large base, and test the effect of the size of the base upon stability.

Centrifugal Force

122. Attach a light but strong thread to a hollow rubber ball. Swing this ball in a circular path about the hand, making the radius 2 feet. In the other hand hold a sharp knife. Prepare to cut the string just as it is horizontal and the ball is moving upward (at *b*, Fig. 23). Now swing the ball rapidly and cut the thread. Note the direction in which the ball now moves. The tendency of the ball, moving freely, is to go in

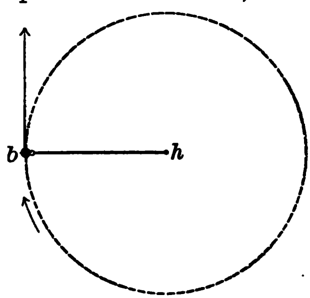


Fig. 23

what sort of a line? What makes it move in a curved path when attached to the thread? Toward what point does this force act? Give two reasons for thinking that there is a reaction against this force. What is the direction of this reaction? How does it compare in intensity with the action? What is it called?

123. Attach a stronger string to the ball (Ex. 122) and whirl it rapidly, having a 10-inch radius. Again swing it with a 30-inch radius, moving the hand at exactly the same rate. Compare the speed of the ball in the two cases. In which case is the centrifugal pull greater?

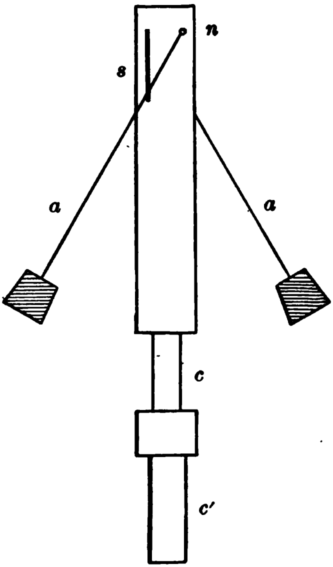


FIG. 24

124. The device shown in Fig. 24 may be easily made. Get a stick of wood ¾ inch square and 10 inches long. Whittle it till round at the points *c*, *c′*, as indicated. Bend two wires, *a*, *a* (size about 12 gauge), to a small eye so that they may turn easily upon a small nail *n*. Fasten a stopper to each wire, and then have the whole wire about 4 inches long when ready to attach. Now fasten one wire by the nail, *n*, through its eye, and fix a staple beside the nail at *s* to help make it secure; but fix *s* so that the wire may hang as in the figure and yet be free to rise to a position nearly horizontal. On the opposite face of the stick fasten the other wire in the same way. Place the end *c′* in a socket made by boring a hole in a wooden block. Wind a string about the stick at *c*, and

whirl the whole by pulling the string while you hold fast to the block. State the effect upon the wires and stoppers. Vary the speed at which you rotate the stick and state the corresponding effects upon the motion of the wires.

125. At two opposite points on a small pail fasten stout strings by which it may be held with its rim level. Fill the pail with water. Twist the strings tightly together, the pail resting upon the table. Grasp the ends of the strings, lifting the pail, and then pull them in opposite directions. This should unwind the strings and rotate the pail. Note the effect of this rotation upon the liquid in the pail. State all that you observe.

Note. Many examples of the centrifugal tendency are common. Ex. 124 illustrates the use that is made of this force in governors for steam engines, and sometimes for steadying the motion of other mechanical devices. Centrifugals for depositing sediment in various scientific work operate similarly. Ex. 125 illustrates centrifugal dryers as used in laundry work, in drying salt and sugar crystals, etc.

Pendulum

126. Make a pendulum of a small strong thread and a heavy "bob" (best use a lead ball). Let it oscillate. Why does it swing downward? Why does it then swing upward? What force opposes its upward swing? Compare the effect of this force upon the bob during its upward swing with that during its downward motion. If this force alone acted upon the pendulum, how long ought it to continue swinging?

127. Make a pendulum with a bob which has little mass in proportion to its size of surface. (A common "Christmas ball" is good, or a wad of tissue paper.) Let this vibrate and note the lengths of successive arcs through which it moves. What do you see that you did not notice in Ex. 126? What impedes the motion of the pendulum, presently

stopping it? Does this affect all pendulums swinging in the air? (Note that the pendulum of a clock, which swings indefinitely, is impelled slightly on each swing by the action of the escapement.)

128. Let the pendulum (Ex. 126) swing through an arc of 30° and count its beats for ten seconds. Again, with an arc of 60°, count the beats for ten seconds. Does the length of its arc affect the rate of vibration of the pendulum? (If one arc were very small and the other very large, a slight difference might be noted.)

129. Make two pendulums of exactly equal length, having light and heavy bobs of the same material. (Consider the "length" as being from the point of suspension to the center of gravity of the bob.) Count the beats of these for ten seconds each. Does the weight of the bob affect the rate of vibration?

130. Vary the length of a pendulum, letting it vibrate for a few seconds at each length and noting its rate each time. Does the length of the pendulum affect its rate of vibration? How?

131. Make a pendulum with a small lead bob (e.g. a bullet) and a fine thread. Making exact measurements for length, vibrate this successively with lengths of 1, 4, 9, and 16 dm. At each length count the beats for fifteen seconds and repeat for accuracy. Write in a column the lengths (1, 4, 9, 16) of the pendulum, and opposite each length write the number of beats in the given period. From these figures make a statement of the relation between the length of a pendulum and its rate of vibration.

132. Using a small, heavy bob and fine thread, make a pendulum 1 meter long. Carefully count its beats for ten seconds; then vary its length until it will exactly "beat seconds," — once every second. Do this very accurately; then measure the length of the pendulum. State this length.

Would the "seconds pendulum" be of the same length at all parts of the earth? Why?

Note. The pendulum is used as a regulating device for clocks and some other instruments. As a metronome it is used to "beat time" for music, and in the laboratory it is useful in marking short intervals of time. Other uses are made of the principle in science and in common practices.

Falling Bodies

133. Get two compact solids of the same material but of different sizes. Drop these from the same height at the same instant. Do they reach the floor together? Does the size of the body affect its rate of falling?

134. Get two compact solids of different material and mass, as of wood and of iron. Repeat Ex. 133. With compact solids does the material affect the rate of falling? Does the mass (or weight) of the body affect its rate?

135. Drop two bodies from different heights, one distance being twice the other. Compare the rates at which these are going when they strike the floor. What general relation seems to exist between the distance the body has fallen and the speed at which it is moving?

136. Make a long trough (20 feet if possible) like Fig. 25 in cross section. It must be smooth and rigid, so that when set up as an incline it will give a constant slant throughout its length. Get a smooth, fairly heavy ball to run in it (a smooth baseball may do), and incline the trough so that the ball will require more than three seconds to descend it. Arrange a pendulum to beat seconds, and to make a ticking sound at each beat. Get an assistant to release the ball, or arrange some device by which you can do this from any place along the trough.

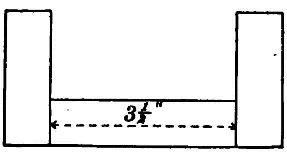


Fig. 25

Have the ball at the upper end of the incline, start the pendulum, and at any tick release the ball. Carefully note the point to which the ball has rolled at the next tick (time, one second). Place some indicator there and repeat several times, taking the average and leaving the indicator at that point. Likewise find the point that the ball would reach at the second tick (two seconds). Again find where it would be at the end of three seconds. Measure the three distances (0–1, 1–2, 2–3) and express these in terms of the unit distance, 0–1. Opposite each distance write the number of the second,—1st, 2d, 3d. What relation do you find between the number of the second of the body's descent and the distance it moves during that second?

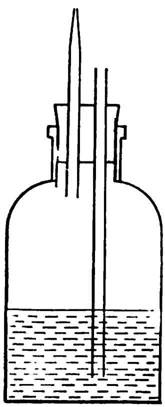


FIG. 26

Since the ball is moved by gravity alone, and the opposing friction is almost nothing, its rolling down the incline may be taken as a fair indication of how a freely falling body would move. Compare the result you obtain with the law of falling bodies for distance covered in each unit of time.

137. Using the results of Ex. 136, measure the total distances covered in one, two, and three seconds,—i.e. 0–1, 0–2, 0–3. Express these in terms of the unit distance, 0–1. Opposite each write the number of seconds the body has been moving,—1, 2, 3. State the relation between the time a body has fallen and the distance it has covered.

138. From various heights let fall a baseball upon the same spot. Judge the force with which it strikes by the sound it makes and by its rebound. State the relation between the distance the body has fallen and the force with which it strikes. Explain fully why this is so.

139. Drop a penny and a feather together from a height and note their fall. Do the results seem to disagree with

what you have learned above? What factor is here important which has formerly been neglected?

Drop a sheet of tissue paper and note its fall. Now crumple it to a small wad and repeat. What do you see? Have you changed the mass of the paper? What factor have you changed?

140. Pour water from a height in a fine stream. A device like Fig. 26 may serve to make the stream fine. Note what happens to this stream in falling. Explain it.

NOTE. Falling bodies are used as pile drivers, "skull crushers" for breaking up scrap iron, ore stamps, trip hammers, etc. When these have a constant mass their momentum may be varied by varying the distance, and hence the speed, of their fall. Ex. 139 shows the effect of the air upon bodies having small mass in proportion to the surface they expose, as paper, feathers, ashes, and dead leaves. Ex. 140 illustrates the atmospheric effect as used in making shot.

LAW OF MACHINES

Pulley

141. Hang up a single pulley (as near frictionless as possible). Pass a cord over this. On one end tie a 500-gram weight and to the other fasten a spring balance. Note the force required to balance the weight. What is gained by using a single fixed pulley?

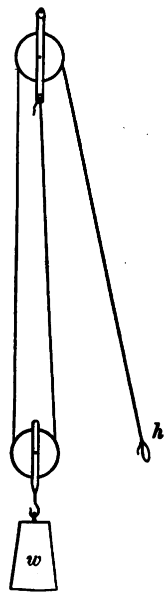


FIG. 27

142. Add to a single fixed pulley one movable pulley, arranging the cord as in Fig. 27. Put an equal weight (500 g.) on the movable pulley. Pull down on the cord and compare the distance the hand moves with that through which the weight moves. How does this relation compare with that

of the number of strands attached to each? What is sacrificed in using the movable pulley? What should be gained? Lift the weight by use of the single pulley (Ex. 141), and then lift the equal weight, using the movable pulley. Do you note the gain you expected?

143. Arrange movable pulley and weight as in Ex. 142, but tie a spring balance where the hand was applied. Note the force required to balance the weight. Call this F, the weight R, the single strand (1) S; and the two strands that lift the weight (so making its distance $\frac{1}{2}$) give for S' $\frac{1}{2}$. Verify the Law of Machines as applied in the movable pulley.

Make other combinations with more movable pulleys and note the ratio of gain in each case. With three movable pulleys, dividing the rope into six strands, what would be gained? At what sacrifice?

NOTE. Movable pulleys are in widespread use for handling heavy material, as in quarrying, in foundries and shops where heavy machines or parts are made, in building bridges and steel-frame structures, and in handling cargoes of vessels or loads of freight cars. They are commonly used by means of cranes and derricks. They are also used to aid in hauling heavy bodies, as in moving buildings.

Lever

144. Use a ruler as a lever of the first, second, and third class. Draw three lines, and upon these indicate the relative positions of the fulcrum and points of application of the force and resistance for each class. State what may be gained by the use of a lever of each class.

145. At its central point bore a smooth hole in a ruler. Fasten the ruler upon the end of a stick (1 inch square) by means of a screw through the hole. Fix it so that it will turn very easily upon the screw. Hold this horizontally (Fig. 28), and if the two sides of the ruler do not exactly balance, cut a bit from one side till they do. Hang

two equal weights, one on each side, and move one till they balance exactly. Compare their distances from the center (the fulcrum).

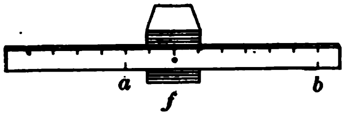


FIG. 28

Now place one weight twice as far from *f* as the other. What must you do to make the two sides balance without varying the distances? As the distance of a point from the center increases, what is true of the effectiveness of the force applied at that point?

146. Mark any point, *a*, near the fulcrum (Ex. 145) and another point, *b*, three times farther from *f* on the other side of it. Move the lever up and down, noting the relative distances (S and S') that these points move. How does this ratio (S to S') compare with that of the lever arms to each other (*fa* to *fb*)?

Hang varying weights upon the lever (Fig. 28), each time varying the distances till the two sides balance. Each time multiply the units of mass on one side by the units of distance from *f*; do the same for the other side. Compare the products. What result do you find holds true in every case?

147. Make steelyards by suspending a stick of wood on a stout wire, as in Fig. 29. Fasten a hook into the larger end and make a rider by fastening a loop of twine to a weight, say 50 g. Make it so that the whole will balance on the wire when the rider is about as in Fig. 29. Mark the position of the rider when the whole balances. Then place different weights (as 1 oz., 2 oz., etc.) on the hook, each time moving *r* till the whole balances, and marking where *r* is placed. Thus a scale may

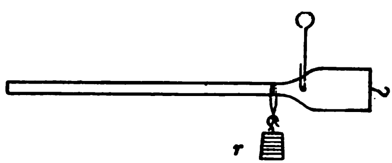


FIG. 29

be made so that the "steelyards" may be used in weighing small parcels. As the weight varies, what must be done to the rider?

148. Use a ruler as a crowbar is used in prying. Measure the force arm and the resistance arm and state the ratio of gain.

149. Examine any or all of the following levers, and in each case state the class of lever, what is gained by its use, the ratio of gain, and the figures whereby you found out the ratio: pincers, sugar tongs, claw hammer (as used to pull a nail), screw-driver (as used to pry up a box cover), nut cracker, plumbers' shears, stove-lid lifter, a straight whip (as used in "cracking"), tailors' or printers' shears, cranks (as bicycle pedals, ice-cream freezers, some stove shakers, etc.), ice tongs, cutting pliers.

NOTE. Levers and the principle of leverage are so commonly applied that any list would be but a hint. There are many examples of levers in the bony and muscular mechanism of the body; also in many of our movements, and in the handling of things, we unconsciously use the principle of leverage. Crank motion is commonly seen in machines, and the principle of levers is a very important factor in an endless variety of machines.

Wheel and Axle

150. Make a wooden axle to fit tightly in some grooved wheel. Fasten two cords, one upon the rim of the wheel and the other on the axle, and wind these so that when one is unwound by a pull the other will be wound up. Arrange the whole in some solid support in which it may be turned.

With one cord in each hand, pull them to and fro, noting the relative distances the hands move. Compare these distances with the forces exerted by each hand. State a general conclusion from your observations.

151. Measure the circumferences (or diameters) of the wheel and axle. If a force is applied at the rim of

the wheel and a resistance at the axle, what is gained? How great ought this gain to be? Attach spring balances to the cords and verify your answer to the previous question.

Note. The wheel and axle is used as a capstan on shipboard for hauling the anchor. As windlasses the principle is applied in moving heavy bodies along the earth (as in moving buildings, hauling up boats from the water, etc.), in lifting buckets from mines or from wells and dredges from the water. Hand brakes on cars also commonly apply this principle.

Screw

152. Using a screw-driver, drive a common screw into wood. Note the points of application of the force and the resistance, and the distance each moves at one turn. Now measure the circumference of the handle where you applied the force; then measure the distance between two threads (the pitch) of the screw. In the equation $FS = RS'$, what does this latter distance represent? What is the ratio of gain in using the screw-driver?

153. Use a common wrench to screw a nut upon a bolt. Note the point where you apply force. What can you measure in order to determine the ratio of gain here? Make these measurements and record them. Compute the ratio of gain and record the computation and the result. How could you secure a greater gain in force upon this same nut?

Note. This principle is applied in the common vise, in the copy press and other screw presses, in various clamps and thumbscrews, in various valves upon steam and water pipes (faucets), and in jack screws for lifting heavy things. Some of these may be used as the screw and the bolt and wrench (Exs. 152–153) to illustrate the law.

Wedge

154. Drive the blade of a jackknife into a piece of wood parallel with the grain, as in Fig. 30. Measure the

width of the blade at this part, and then measure its thickness. Compute the ratio of gain when the knife blade is thus used as a wedge.

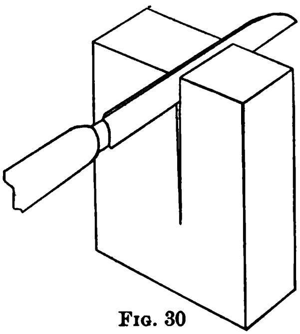


Fig. 30

Note. Wedges are used where great force is needed to separate things or to split something, the great force acting through a short distance only. The force is frequently applied to the wedge as a series of blows. Thus blocks of rock are quarried, logs are split, etc. An ax or a hatchet serves as a wedge in splitting wood, and as a crowbar when used to loosen rocks, etc.

Inclined Plane

155. Make an inclined plane in any convenient way, but preferably so that a pulley may be placed at *c* (Fig. 31). Make a car (2) to run with little friction. Put various weights on the car and balance these with weights at *e* so that it will not move. Allow for the weight of the car and for any possible friction; then state the ratio of gain in using the incline as against a vertical lift. Measure the sides *ac* and *bc* and compare these with the results just stated.

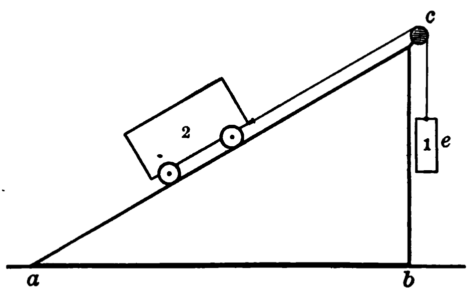


Fig. 31

If possible, vary the angle of the incline. In each case compute the ratio of gain. Then test it by the use of weights, as above, or by first weighing the

car and contents, and then with the same spring balance measuring its pull when held at rest on the incline.

Note. The inclined plane is a modified wedge. It is used in loading and unloading heavy objects, in elevating vehicles, in carriers, such as those that lift coal and ore to blast furnaces. Stairs are a sort of inclined plane. We could hardly jump the distance from one floor to the next, but the stairs permit a series of short lifts.

Gears

156. Fasten upon axles of equal diameter two toothed wheels of unequal sizes, but made to run upon each other. Fix these in some support. Wind a cord upon each axle so that when one is unwound the other will be wound up. Tie spring balances to these cords. Now count the teeth in each wheel. As force is applied at the axle of the larger and resistance at that of the smaller, what will be gained and at what ratio? If F and R were applied at the reverse positions, what would be gained and at what ratio? Now pull upon the spring balances till both are at rest and then read their scales. Verify your answers as given above.

Note. This principle may be applied either by toothed wheels (cog-wheels) engaging each other, or by the flat rims of two wheels touching (as the bobbin winder of some sewing machines), or wheels may be connected by belts or by chains (as the sprockets of bicycles, etc.). It forms a very important method of transmitting and varying the effects of forces, and its applications in machinery are too numerous to be listed here.

Friction

157. In the end of a wooden block (about $8 \times 2 \times 1$ inches) fasten a screw eye. Using a spring balance, draw the block along a level surface. Does force have to be exerted to do this? What, besides inertia (which is overcome as soon as the block is moving at the set rate), must this force overcome?

Place weights upon the block and draw these, noting the force required. Vary the weights and note any possible variations in the forces used to draw the block. State the effect of pressure upon the greatness of the friction.

158. File one face upon each of two iron blocks (large nuts) till it is smooth, but flat (not at all rounded). Clean and dry these faces and rub them together, varying the pressure. Verify your answer to the last question in Ex. 157. Now cover these faces with good machine oil and again rub them as before. What effect, if any, has the oil upon the friction? Explain fully why this is so.

159. Make several rollers by cutting pieces of lead pencil into lengths equal to the width of the block (Ex. 157). Load the block with weights and draw it along over the table. Then place the rollers under it and draw it along, keeping the rollers constantly beneath it. What effect upon friction do you observe when a rolling contact is substituted for a sliding contact?

NOTE. Friction is both useful and inconvenient. It is very useful as a source of heat in kindling matches. Brakes stop cars, etc., by friction upon the wheel rims; machines are connected with engines by belts and pulleys which involve friction; knots and rope wound upon posts or cleats do not slip when the friction of such motion becomes greater than can be overcome by the pulling force. Friction is diminished by use of lubricants, cone bearings, ball and roller bearings, and by making the two parts that rub upon each other of certain different kinds of metal.

HEAT

Sources of Heat

The Sun

160. Fill two 4-ounce bottles with water from the same source. Test and record their temperatures. Place these where the temperature of the air is the same, but so that one is in the direct sunlight and the other is not. After some minutes test their temperatures again. State the result. What do you infer from this?

161. With a convex lens converge the sun's rays to a small spot upon a piece of paper. Hold it steadily so that this spot will fall at the same place on the paper for some moments. How much of the sun's radiation is converged to this point? What is the result?

Chemical Action

162. Pour cold water upon a little fresh lime in a test tube. (Water and quicklime act upon each other chemically.) Feel of the test tube. What is produced as one result of this chemical action?

163. Into 5 cc. of hydrochloric acid in a test tube put a few bits of zinc. What signs of chemical action do you see? Feel of the test tube. What has been produced?

164. Burn a piece of wood. What sort of an action is ordinary burning? What is one result of the burning?

Friction and Percussion

165. File an iron nail vigorously. Feel of the nail. What sort of energy did you use in filing? Into what was some of this energy changed?

166. Vigorously saw a hard-wood stick; then feel of the saw.

Rub a metal button upon a woolen cloth and feel of the button.

Rub a common match lightly over some surface; then increase the vigor of the rubbing till the match is kindled. The tip contains a substance which kindles easily. How is the necessary heat produced?

167. Lay a soft-iron nail upon some hard support and pound it vigorously with a hammer. Feel of the nail and state the result. Note that this requires effort.

With the point of an old file strike sharp blows upon a piece of flint. After a little practice it is not difficult to produce a display of sparks. What name is applied to this method of developing heat?

Compression

168. Use a common bicycle pump. Closing the tube with the finger, briskly operate the pump. The tube being closed, the air is compressed at each stroke. After a few moments' work feel of the pump barrel. State the result and the method by which it was brought about.

Electrical Action

169. Make a battery of two or more strong cells connected in series (Ex. 274). Into the circuit introduce a ½-inch piece of fine iron wire (about 30 gauge). This offers great resistance to the passage of the electric current. State the effect upon the wire when the current is so passing through

it. The copper wires (used to help form the circuit) do not offer such high resistance. Are they equally heated?

NOTE. Many illustrations of these methods of producing heat are common. Each method has been of more or less use. That from the sun and from chemical action (combustion or fires) is too widespread to need discussion. Friction produces the heat that kindles ordinary matches; percussion was formerly in use when flint, steel, and tinder were in demand for kindling fires; compression helps raise the temperature of gases in certain internal-combustion engines; and electric currents are used in various heating and lighting devices. The highest temperatures produced upon earth are obtained in the electric furnace.

TRANSFER OF HEAT

Conduction

170. By means of paraffin fasten marbles upon an iron rod, 3, 4, and 5 inches from one end. Place this on a tripod, as in Fig. 32, and heat the end by a steady flame. Watch for a result and state it. State any evidence that heat travels along the rod. Does it travel rapidly in this way? What is this method of heat transfer called?

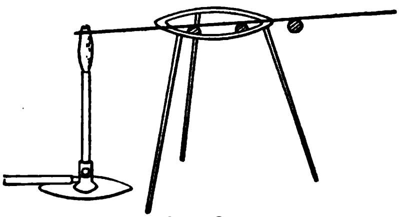


FIG. 32

171. Upon a stick, at intervals of 1 inch, fasten rods of iron, copper, and brass (wires about 10 gauge will do) so that they will converge to a point (Fig. 33). On each wire, at a point 4 inches from the end *a*, fasten a marble by using paraffin. Apply strong heat at *a*, noting the fall of the marbles. State the time needed before each drops. What would you infer as to the relative conductivity of these metals?

172. Four inches from one end of a clay pipe stem fasten a marble by paraffin. Place this on a tripod and apply heat

to the end of the pipe stem, taking care that the heat shall have no other means of reaching the paraffin except by conduction. State the result. What do you infer from this?

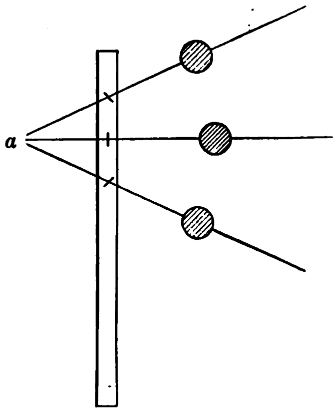


FIG. 33

173. Let a vessel of water stand in a room till its temperature is the same as that of the air about it. Now dip the hand into this water. Does it feel any warmer or colder than the air? Which takes the heat from the hand more rapidly, the air or the water? Which is the better nonconductor of heat?

NOTE. Heat is not commonly transferred by conduction except for relatively short distances, — a few inches. Nonconductors, or insulating substances, often serve important uses. Steam and water pipes are covered to prevent loss of heat; furnaces, stovepipes, and the like are separated from any woodwork near them by some nonconductor, to prevent fires; wooden handles, cloth "holders," and asbestos mats are common in household uses; carpets help keep rooms warm, while double walls, double windows, and storm doors serve (by inclosing air spaces) to make houses more comfortable; our clothing, like the fur of animals, serves to retain the bodily heat.

Radiation

174. Spread the palm of the hand to face the flame of a lamp, about 6 inches from it. What do you note? Now, without removing the hand, place a sheet of cardboard so as to form a complete screen between it and the flame. What effect do you observe upon the hand? From this exercise would you infer that the hand is warmed from the air, or directly from the flame by some means other than conduction?

175. Cover two like test tubes with one thickness of cloth, black around one and white around the other. Fill these with water from the same source and test their temperatures. Put both in the sunlight, under exactly the same conditions. In ten minutes test their temperatures again. State the result. From what source were these tubes of water heated? By what means was the heat transferred to them? What was the only difference in the conditions surrounding them? Does the amount of heat received by radiation seem to depend at all upon the body receiving it?

To show the difference between the warming of land and water upon earth, fill one saucer with water and another with loose soil. Let them stand till the thermometer shows their temperatures to be practically the same; then place them in strong sunlight under exactly the same conditions. In a few minutes note their temperatures, sinking the thermometer bulb equally into them. State the results and the inference.

NOTE. Radiation is an important means of transferring heat, inasmuch as we get heat from the sun by this means. Heat radiated from the earth helps warm the air, and in "cold frames" etc. this is useful.

Convection

176. Hold a test tube of water by the bottom and apply heat to the water at the top till it boils. Does the heat travel readily through the water by conduction?

Now refill the test tube with cold water and apply heat at the bottom, holding it near the top of the water by the hand. Can it be thus held till it boils? (Do not attempt to do so.) Make a full statement of the differences between these methods of heating the water, and of the results.

177. To the neck of a pill vial, and also to the stopper, fasten wires, each about 1 foot long. Fill a deep glass vessel (e.g. an hydrometer jar) with cold water. Color a little

water strongly with cochineal or ink, heat it nearly to boiling, then pour it into the pill vial and set the stopper loosely in place. With a wire in each hand, lower the vial at once into the cold water as far as possible; then pull out the stopper. State the result. In a mass unequally heated what becomes of the warmer water?

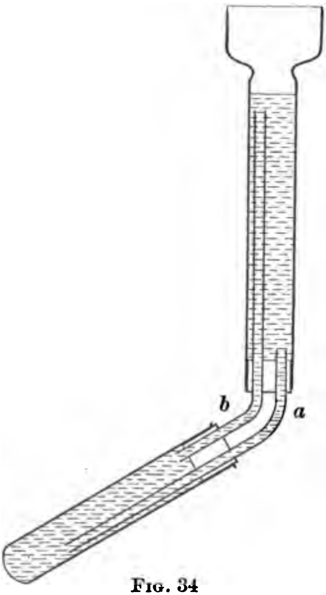


FIG. 34

178. Completely fill a 6-inch test tube with cold water. Without spilling a drop, pour this into a large (8-inch) test tube and heat it nearly to boiling. At once pour it back into the smaller test tube. Does any remain in the large test tube? What did the heat do to the water? Is there as much matter in the small test tube now as there was before heating the water? How would the tubeful of warm water compare in weight with the same volume of cold water? With these facts in mind, explain what you observed in Exs. 177 and 176.

179. Bend two glass tubes like *a* and *b*, Fig. 34. Fit these, as in the figure, into rubber stoppers that fit an 8-inch test tube and a student-lamp chimney. Clamp the whole device, securely fitted together, into a ring stand, the chimney being vertical, and fill with water, as the figure shows. Apply slow heat to the water in the test tube. In a moment sprinkle fine sawdust or powdered cochineal on the water to show the movement of the water. Describe the result, with an explanation.

180. Place a short piece of candle, lighted, upon the table; beside it lay two small sticks, $\frac{1}{4}$ inch square on the end. Upon these sticks place a student-lamp chimney, which will then be lifted $\frac{1}{4}$ inch from the table. Make a smoke by burning a bundle of strings, and place the smoking source close to the openings below the chimney. State the result. Fully explain this.

Remove the sticks so that the chimney will rest upon the table. What effect has this upon the burning of the candle? Why?

Note. Convection is an important means of transferring heat in fluids. Ex. 179 shows how it is used in heating water for household use by "water fronts" (the test tube) in the kitchen stove, and hot-water heaters for buildings work similarly. Heating water, etc., upon a stove, air in hot-air furnaces for houses, air in lamps or stoves as drafts, and the production of winds, — these are things involving convection.

Temperature and Thermometers

181. Let a tumbler of chipped ice stand in the room till it shows signs of melting. Into the midst of the melting ice lower the bulb of a thermometer (having a scale on its stem) till you can just see the end of the mercury above the ice. Carefully make three separate readings of the scale. State the result. What is the melting-point error of this thermometer?

182. Let water boil in a flask. Lower a thermometer into the steam within the flask so that the whole of the mercury column will be in steam. Make careful readings of the scale and state the result.

To test the boiling-point error of the thermometer, read the barometer at the time of testing and write the reading in centimeters. Allow 1° C. for every 2.7 cm. below or above 76 cm., subtracting this from 100° C. if the air pressure is below, and adding if it is above. With the result of this computation, compare the reading obtained and note the error.

Quantity of Heat

183. Into a large glass jar put 500 grams of cold water, carefully weighed. Note its temperature. Again weigh 500 grams of hot water, note its temperature, and then pour it into the jar of cold water. Quickly stir these thoroughly and take the temperature of the mixture at once. With these three temperatures, and knowing the masses of water, compute the amount of heat lost by the hot water and gained by the cold water when they were mixed. Express the results in calories or gram calories. (A gram calorie is the amount of heat required to raise 1 gram of water from 0° to 1° C.)

Specific Heat

184. Carefully measure 200 g. of cold water and record its temperature. Now wind iron wire (about No. 12) into a small coil, which shall weigh any convenient amount, say 200 g. Weigh this carefully and record the weight. Now suspend this coil in steam for five minutes or more till its temperature is that of the steam. Then transfer it speedily to the cold water, letting it remain there till it has the same temperature as the water. Note and record the temperature of the water now. How many gram calories of heat has the water taken from the iron? How great a change has this made in the temperature of the iron? Compare the amount of heat required to raise 1 gram of iron 1 Centigrade degree, with that needed to do the same to 1 g. of water.

Heat Effects: Changes of Volume

Solids

185. To a long board firmly fasten a smaller piece (as *a*, Fig. 35). In *a* make a small hole and fasten an iron rod. Place a block *b* near the end of the rod, and on each side of

it tack a strip of wood to the board so that *b* can be slipped to and fro along the rod. At the end of *b* fasten two small screw eyes, *c*, so that they will be off the end of *b* and above the rod. Make a pointer *d* as long as possible (cut it from "tin" and curl the end so that it will hang upon a wire

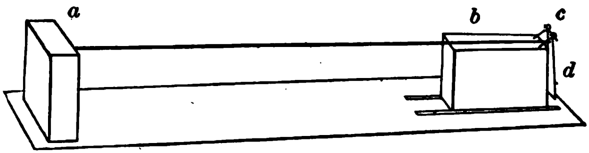


Fig. 35

passed through the screw eyes). With *d* adjusted, move *b* till the rod just touches *d*; the rod is then just below the wire on which *d* hangs, so that a slight push by the rod would make the lower end of *d* move perceptibly. Now apply heat along the rod. Note the pointer and account for what is seen. After a time remove the flame and watch the pointer. What is seen?

186. Secure two screw eyes, one of which will just fit easily into the other. Fasten these into handles. Heat the smaller and try to pass it through the larger, just as before. State the result. What, in general, is the effect of heating and cooling upon these solid bodies?

187. Get two perfectly straight wires, one of brass and one of iron (about No. 10 gauge and 6 inches long). Bind these firmly together with fine wire at four or more places along their length. Lay this pair upon a tripod and heat it thoroughly. What does this do to the pair? (Look along it, with one end towards you.) Account for this result. Does heat cause an equal expansion in these two metals?

Note. Expansion and contraction are useful in riveting boilers and structural steel work; the rivets being put in hot, they contract on cooling and make tight joints. Likewise tires are put upon wheels, metal parts are "shrunk" upon each other to fasten them very tightly,

stoppers are loosened in bottles, etc. The principle shown in Ex. 187 is useful in compensating balance wheels of watches and in pendulums, where slight changes in size (due to temperature changes) would make a difference in their rates of movement. Two metals are so arranged that their inequalities of expansion shall just neutralize the effect upon the pendulum rod or balance-wheel rim as a whole.

Liquids

188. Cut a 12-inch piece of glass tubing of small bore to fit the 1-hole stopper of an 8-inch test tube. Fill the test tube with cold water so that when the stopper is in place the water will rise into the small tube. Have no air in the test tube. Tie a string to mark the height of the water in the small tube; then gently heat the water in the test tube. What is the result? What does it indicate?

Set the whole aside to cool and state the result. What does this show with regard to the effect of cooling hot water?

NOTE. The expansion and contraction of liquids is used in thermometers, where mercury or alcohol is commonly employed. Also the regulating devices of some systems of heating buildings make use of this principle.

Gases

189. Use the device of Ex. 188, but without any water. Hold the test tube over a slow flame, with the glass tube opening under water in a tumbler. What is in the test tube? As this is heated what do you note? Account for it.

Without removing the tube from the water, withdraw the flame. What happens now to the contents of the test tube? With what result?

NOTE. The volume of a gas is so much altered by changes in temperature that the principle can be used to do work by means of engines. Hot-air engines use air alternately heated and cooled; the pressure of steam is much increased by "superheating" it; the now common internal-combustion engines explode a mixture of gases, and the mixture expanding as it burns, exerts much force.

Water

190. Put a piece of ice into water. State what happens. What does this show with regard to the weights of equal volumes of water and ice? What happened to the water as it froze?

NOTE. Water is at its greatest density when its temperature is 4° C. above 0.

HEAT EFFECTS: CHANGES OF STATE

191. Test the temperature of chipped ice that is melting in a tumbler. Use the thermometer that you corrected (Ex. 181). State the melting point of ice.

Place a dish of water where it will freeze. When this process has just begun, immediately test the temperature of the water with the same thermometer. What is the freezing temperature of water?

192. Boil water in an open dish, testing its temperature with the thermometer corrected in Ex. 182. (Put this in while the water is cold, and keep it there.) At what temperature does the water boil? (Note that this can be told only when all the water is at this temperature,—not at the first signs of bubbling, etc.) Does the water rise in temperature after this?

193. Boil 25 cc. of water in an 8-inch test tube. After this has boiled thoroughly for a minute, remove it from the heat and immediately thereafter cork the test tube tightly. Does the water now show signs of boiling?

Pour a little cold water over the test tube and state the apparent effect on the water within. (The cold water condenses the steam which fills the test tube, leaving a greatly reduced pressure on the water therein.) Is the water now as warm as when removed from the heat? What effect

has the reduction of the pressure upon the boiling point of the water ?

NOTE. The melting point and the boiling point may be found for other substances. Crystalloids have definite melting points. Ex. 193 illustrates a method used in evaporating sirup and brine (in sugar and salt making), in preparing condensed milk, etc.

Evaporation

194. In each of three like saucers put 25 cc. of water. Place one saucer where it will be at ordinary room temperature, another in warmer surroundings, and the third where it will be cold, without freezing. Note the time which elapses before each saucer becomes dry. What factor affecting rate of evaporation have you varied ? What general inference can you draw from this ?

195. Fill a test tube with water, after pouring an equal amount into a saucer. Place these where they will be subject to the same conditions of air, temperature, etc. What factor affecting rate of evaporation is here varied? Compare the intervals that they require for evaporation. What is the inference from this exercise ?

196. Pour 5 drops of alcohol into a watch glass and note the time, in minutes and seconds, required for evaporation. Again put 5 drops in the same watch glass, but make a movement in the air above it by fanning or blowing. Observe the time required for evaporation under these conditions. What factor affecting evaporation has here been varied ? With what result ?

197. Make a strong solution of common salt in water. Evaporate a few drops of this on a watch glass ; also boil some to dryness in a teaspoon. When the salt solution is evaporated, either slowly or by heating, does the salt go off with the water ?

NOTE. We use these principles when we seek a warm place for drying things; when we shake out clothing and hang or spread it to expose much surface, or place things in broad shallow pans to evaporate the liquid in them; when we seek a windy spot for drying, or blow upon ink to dry it. Ex. 197 shows an important fact; because of it we can recover dissolved substances from their solvents, as salt from sea water or brine, sugar from the juice of cane and beets, etc.

Condensation

198. Half fill a tumbler with chipped ice and make sure that the outside of the glass is dry. Place this in a warm room and in a few moments examine the outside of the glass. What do you observe? Where did this come from? In what state was it just before it gathered on the glass? What effected the change? To what process in nature is this similar?

199. Fit a glass delivery tube into the 1-hole stopper of an 8-inch test tube. Put 25 cc. of water in the test tube, insert the stopper, and boil the water well. Note the end of the delivery tube. What is seen there? Of what is this composed? From what was it formed? By what process? What in nature resembles this in make-up and in the general manner of its formation?

200. Repeat Ex. 199, but direct the cloud upon the sides of a bottle full of ice or cold water. State the result. What purpose is served by the cold glass? (It collects the cloud particles into larger drops.) What phenomenon in nature does this represent?

201. In very cold weather breathe upon a clear, cold window pane and watch the formation of crystals of frost; or mix ice and coarse salt in a tumbler till it is very cold and then breathe upon it. Does the frost crystallize directly from the vaporous (gaseous) state or does the vapor first become liquid and then freeze? What natural phenomena are illustrated by this?

Distillation

202. Fit two 2-hole stoppers into a glass tube (*a*, Fig. 36) about 15 inches long. Insert a long glass tube, *bb'*; also two short tubes, *c* and *d*. Support *a* on an incline, as in the figure. Connect *c* by a rubber tube to a faucet with running

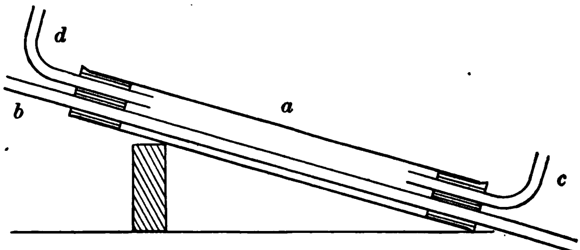


FIG. 36

water, and connect at *d* a tube that will carry off the overflow. Insert a short glass tube in the 1-hole stopper of an 8-inch test tube and connect this tube with the end *b* by a rubber tube. Now boil water in the test tube; steam should pass through the rubber tube and *bb'*. Let the cold water from a faucet flow slowly through *c* into *a* and out at *d*, thus keeping *bb'* surrounded by cold water. What is the effect of this upon the steam in *bb'*? Place a tumbler at *b'* and collect the water. The rubber tube from the test tube to the condenser should not be too long; also the water should boil vigorously enough to drive the steam over into *bb'*.

Lacking the tube *a*, a student-lamp chimney (Macbeth No. 48) may be used as follows. Clamp it upright upon a ring stand and have the tube *bb'* run downward through it, and a 2-hole stopper in its lower (the smaller) end. Let cold water run in through *c*, but for *d* substitute a siphon of glass tubing with small bore. Adjust the flow through *c* so as to keep pace with the outward flow through the siphon,

the upper (larger) end of the chimney being open. Connect with the 8-inch test tube as before.

NOTE. Distillation is used in many important processes, as in the production of alcohol and "spirits," refining of petroleum, preparation of certain "extracts," etc. By this means substances may be purified, especially by being distilled several times. Water is distilled for medicinal and laboratory uses, sea water is distilled on vessels for use in the boilers, and by the same method the exhaust steam from engines is often condensed and used again, — a process which provides warm water to the boilers without much reheating.

Latent Heat

203. Fill a small dish with broken ice and test its temperature. Now apply very slow heat, enough so that it is evident that heat is being applied, but not enough to heat the water locally before melting the rest of the ice. Presently take the temperature of the ice again. Has the heat raised the temperature of the ice? What has it done? What name is given to the heat that produces this change?

204. Carefully measure out 200 grams of water at about 60° C. and carefully note its temperature. Now add to this about 100 grams of dry ice (at 0° C.) and weigh the whole again to get the exact weight of the ice. When this is melted, note the temperature of the water. Write all the figures involved and compute how much heat (in gram calories) is needed to melt 1 gram of ice. This is called the latent heat of fusion of the ice.

205. Fit a bent delivery tube into the 1-hole stopper of an 8-inch test tube and boil some water in the test tube with this stopper inserted. When steam flows vigorously place the end of the tube near the bottom of cold water (of a known temperature) in a tumbler. Note the temperature of the water from time to time and state what is observed. What change takes place in the steam when

it enters the water ? What is the effect of this upon the water ? State the reason for this.

Do not leave the delivery tube in the water unless steam is flowing out of it. Take it from the water before taking the test tube out of the flame.

206. Ex. 205 can be used to determine the latent heat of vaporization of water by using a known weight of cold water in the tumbler and then weighing, when the final temperature is taken, to determine the mass of steam involved. Care must be taken to pass only dry steam into the tumbler.

NOTE. The principle of latent heat is applied in both heating and refrigeration. Ice, and some other convenient substances that require heat on melting or vaporizing, are used in cooling other things, from which they extract the heat they need. Steam in radiators gives out, to the air around, the heat that it loses in changing from vapor to liquid form.

ARTIFICIAL COLD

207. In a tumbler mix coarse salt with three times its volume of chipped ice. Stir this to mix it well, testing its temperature every few moments with a thermometer kept in it. State the result. What does the salt do to the ice? What does this change require ? State exactly how this may be applied, as in freezing cream, to make a particular thing cold.

208. In a common tumbler mix about 25 grams each of ammonium chloride and ammonium nitrate (commercial). Put a little water into a 4-inch test tube. Now add water to the mixture of salts till the tumbler is half full and stir this with the test tube of water. From time to time examine the water in the test tube. What is observed ? What change did the salts undergo ? In making this change what was required ? From what was a portion of this taken ? (If no results are seen, add more salts to the mixture.)

209. Wind two layers of cloth around a 6-inch test tube. Put from 15 to 20 cc. of water (at room temperature) into the test tube, insert a thermometer, and record the temperature. Now pour alcohol over the cloth and gently wave the test tube about through the air. Read the thermometer from time to time. What do you observe? Following the reasoning of the previous exercises, account for this result.

NOTE. Refrigeration on a large scale is usually effected artificially by using the change from liquid to gas, though the other methods are used for some purposes. The ammonia process of ice making and the regulation of our bodily temperature by evaporation of perspiration are evidences of the former.

SOUND

Origin of Sound

210. Strike a tuning fork sharply so that you hear a sound. Look at the fork while it is sounding. Do you see any signs of motion? Again sound the fork, and at once dip the tips of the prongs slightly into water in a tumbler. What do you observe? What does this indicate with regard to the sounding fork? Describe the motion of the prongs.

211. Sound a bell sharply and at once bring its rim into light contact with a glass jar or tumbler. State the result. What is true of the bell while it is giving rise to sound?

212. Put a tumbler of water near one edge of the table and let its surface become perfectly still. At some distance strike the table with the knuckle sharply enough to make a sound but without sensibly jarring the table. Note the water surface. In what condition is the table top while sounding?

213. With the fingers upon the larynx, speak aloud. Do you get any evidence that the voice is accompanied by anything vibrating?

Sound Waves

Nature of Wave Motion

214. Lay a long, flexible rope straight along the floor. At two points about 3 feet apart make clear marks upon the rope. Grasping one end, move the hand quickly forward and upward, then down again to the same place, so as to raise a slight loop that shall travel along the rope. Watch

this loop as it comes to each mark. Describe the movement of each mark. Are these movements alike for the two marks? Are they like the original motion of the hand? Does the point on the rope suffer permanent change of position, or does it return to the place where it first was upon the floor? (Disregard such slight changes as are due to imperfect manipulation.)

215. Roll and paste stiff paper into a tube 3 feet long and 3 inches in diameter. Place this as in Fig. 37, with a

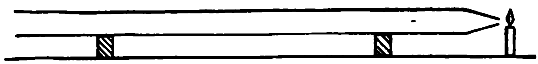


FIG. 37

candle at the end. Burn touch-paper and fill the tube with smoke. Have the candle flame very near the tapering end, and directly at the other end strike two blocks together to make a sharp sound. Watch closely for any effect upon the flame. Note also whether any smoke comes out at the tapering end. Blow into the tube towards the flame to make comparisons. Did the sound produce a pulse of air (a wave) or a bodily movement forward (as did the blowing)?

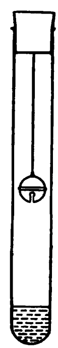


FIG. 38

Media

216. Let somebody scratch one end of a long iron bar with a nail and place your ear close to the other end. Do you hear the noise? Now place the ear at an equal distance from the scratching, but away from the rod. Do you now hear it? Make comparisons. Which medium, iron or air, carries the sound waves better?

217. By means of a stiff wire fasten a toy bell to the inside of a solid rubber stopper of an 8-inch test tube (Fig. 38). Insert the stopper, shake the test tube, and note the sound. Boil 10 cc. of water in the open test

tube vigorously for a minute, remove from the flame, and immediately insert the stopper tightly, with the bell inside. The test tube should now contain steam, but no air, so that by cooling the test tube in water a partial vacuum will be left within. Again shake, note the sound, and make comparisons. Does the rarefied medium transmit the sound waves well?

Velocity in Air

218. Divide the class into two groups. Provide one with a white square of cloth on a short stick, together with some device for making a sharp sound, such as a bell and hammer, or a pistol; give the other group a stop watch. Carefully measure a clear stretch of ground out of doors, say from 200 to 500 yards, and place one group at either end of this distance, giving to one the flag and bell and to the other the watch. Let one member of group A signal three times with the flag, and exactly at the third signal let him strike the bell sharply. A member of group B, watching, will start the stop watch exactly with the third signal and stop it exactly as the sound is heard. Record the exact interval of time.

Let others of each group handle the watch and signals, recording each result. Then let members of B make the sounds while those of A take the time; this will allow for any differences due to wind. Examine the records and exclude any that are clearly so far from the average as to show bungling work in handling the watch. Take the average of the records. This is the time required for the sound waves to travel the measured distance. Compute the distance that they would traverse in one second.

Note the temperature, make the proper allowance for its effect, and see how far the result is from what careful experiment has determined (see *Lessons in Physics*, p. 181).

Reënforcement of Sound Waves

Forced Vibration

219. Vibrate a tuning fork, hold it in the air at arm's length, and note the loudness of the sound, if any is heard. Again vibrate it with equal energy, and at once place the end of its handle firmly upon the table. Is there any difference in the sound? Account for this.

220. Secure an empty box of thin wood, e.g. a cigar box; also get a block of wood as near the size of the box as possible. Vibrate the fork twice, as in Ex. 219, once placing it against the solid block and once against the hollow box of thin wood. State any difference in the resulting sound. Which body is more readily thrown into forced vibration?

Note. Sounding boards, such as those in pianos and the bodies of stringed instruments, serve to reënforce sounds that, without their help, would make little music. Megaphones or speaking trumpets assist in a measure to add volume to sounds, because they are easily forced into like vibration.

Sympathetic Vibration

221. Carefully measure two pendulums till they are found to vibrate at exactly the same rate. (Use lead bobs if possible.) Hang these close together upon the same supporting rod, and equally near to A hang a third, C, which shall be 2 inches shorter. Now let A swing through a wide arc for some minutes and watch B and C. Which would naturally vibrate at the same rate as A? Does it show any signs of vibrating? Does the other do the same? Explain the difference in effect.

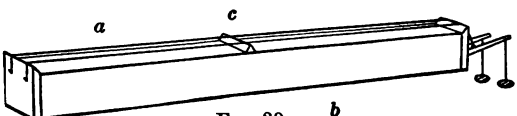


Fig. 39

222. Adjust the two wires of a sonometer (Fig. 39) till they give forth exactly the same tone. Now sound one

of these with energy, but in a few seconds grasp it so as to entirely stop its vibration. Do you now hear any continuation of the tone? If so, what is producing it? What sort of vibration is this called?

Loosen the second string a trifle and sound the two. Is their rate now the same? Repeat the exercise as before. Do you now hear the continuation of the sound? Explain fully.

223. Vibrate a tuning fork over the mouth of a tall hydrometer jar (Fig. 40). Now pour water slowly into the jar, repeating the vibration of the fork, till the sound is distinctly louder. Continue to add water and to test the effect till the sound begins to diminish in loudness. What is vibrating together with the fork? Why does this respond to the tone only when it is of a certain length?

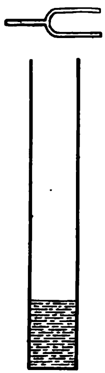


FIG. 40

Use another tuning fork of different tone with the same hydrometer jar and the same amount of water in it. Does this air column respond to the vibrations of this fork? What must be done in order that it may so respond?

NOTE. This principle is applied in a variety of wind instruments, as organ pipes, horns, the flute, cornet, clarinet, etc. Vibration is produced by various means, but the particular tone of the instrument depends partly upon the air column inclosed in it, which responds only to certain ones of the many vibrations produced.

VIBRATION RATE AND WAVE LENGTH

224. If a "vibration rate" apparatus is available, determine the rate of its pendulum by counting carefully for several periods of ten seconds. Compute the time required for one vibration. Now smoke the glass plate over a smoky flame. Lay the smoked plate upon the board, attach a

stylus or bristle to the pendulum and to a prong of the fork, and support these so that they will trace upon the smoked glass at points near together. The pendulum should vibrate transversely and the fork should lie above and parallel to the length of the glass strip.

Vibrate both the fork and the pendulum and then pull the glass strip along beneath them at such a rate that the pendulum shall have traced three or four vibrations upon it. Count the vibrations of the fork corresponding to each complete vibration of the pendulum. (Count from each crossing of the lines to the second one beyond; estimate to tenths of one vibration; take the average of these.) From this result, and the time of one vibration as previously found, compute the number of vibrations per second of the fork.

225. Very carefully find the length of an air column that best responds to a tuning fork, as in Ex. 223, the fork being held close to the mouth of the jar. As one vibrating prong moves downward it sends a condensation of air down the tube; this, reflected by the water, moves up and reaches the prong as it is starting its upward movement; the corresponding rarefaction likewise moves down and up the tube, arriving as the prong is about to begin the second vibration; thus it will be seen that the distance down the tube to the water surface represents one quarter of one wave. Measure the air column and compute the length of one wave from this fork.

With this result, and knowing the velocity of the waves in air (Ex. 218), compute the number of vibrations per second of this fork.

Musical Tone and Noise

226. Cut a circular piece of stiff cardboard about 15 inches in diameter. In this make three sets of holes equal

in size and of smooth edges (Fig. 41). Place those of the outer and inner sets each at regular intervals, but make the outer set to contain just twice as many holes as the inner. Let the middle set have any convenient number of holes, but spaced irregularly. Fix this card so that it may be rotated at a constant speed.

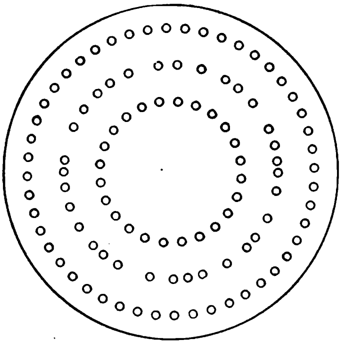


FIG. 41

Rotate the card and blow through a short rubber tube, directing the stream of air first at the inner and then at the middle set of holes. The succession of puffs of air through the holes causes waves which result in sound. What is the chief difference between these two successions of waves? What is the difference in the resulting sounds?

PITCH

227. Rotate the card as in Ex. 226, keeping its speed constant. Blow through the inner and the outer sets of holes. Describe the difference in pitch of the two resulting tones. Compare the corresponding frequencies (number per second) of the two trains of waves that produce these tones.

228. Adjust the two wires of the sonometer to give the same tone. Now move the bridge (*c*, Fig. 39) so that it will divide one wire exactly in halves. Sound one of these halves and compare the pitch of its tone with that of the other (whole length) wire. Again place the bridge so that one wire will be two thirds as long as the other (full length). Name the tone on the diatonic scale that results when this vibrates. Again make the length four fifths of

the whole and compare the tone with the full-length tone. Write the relative wave lengths of the tones *do, mi, sol, do'*, calling *do* equal to 1.

If *do* be considered as 264 vibrations per second, what is the vibration rate of *mi, sol*, and *do'?*

229. Using the sonometer with both wires giving the same tone, show by adding weights to one lever arm the effect produced upon the pitch of a tone by tension on the wire.

230. Secure a long pill vial without a shoulder, i.e. cylindrical throughout. Blow across the top of this, producing a sound. Now put a little water in the bottle and repeat, noting any difference in the tone. Vary the amount of water and repeat. Is the original vibration that you make by blowing affected by this change in the amount of water? Is the resulting sound affected by it? What determines the pitch of the tone that is heard? (See Ex. 223.) State the relation between the length of the air column and the pitch of the tone it reënforces.

Quality

231. The fundamental and a few of the overtones may be shown with an organ pipe or some wind instrument by varying the method and intensity of blowing. With a stringed instrument or sonometer these may be shown by bowing with a varying touch or upon different parts of the strings.

LIGHT

Light Waves

232. Note these objects and tell which are luminous and which are illuminated: a chair, candle flame, the sun, a cloud, a book, glass bottle, glowing splinter of wood, a picture, a red-hot wire. What test do you apply? Whence come the light waves by which each object is seen? Do the rays that illumine some of these fall directly upon the object from their source? If not, by what means do they reach the object? What name is used to describe the condition of the glowing splinter or the red-hot iron?

Intensity of Illumination

233. Cut a cardboard frame about 6 inches square and 1 inch wide (Fig. 42). Upon this paste a sheet of white unglazed paper and tack the whole to a block of wood so that it will stand upright. In the center of the paper screen put a small drop of oil. This spot, being translucent, will show the intensity of illumination on the other side of the paper; thus, if the spot seems dark, it is clear that the side of the paper at which we are looking is more brightly illuminated than the other, and vice versa.

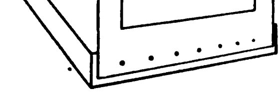


Fig. 42

Place four candles in a row (at *a*, Fig. 43), and put another in a line perpendicular to the row, about 3 feet away (at *b*). Between these, parallel to the row of four, place the screen

(at *c*). Darken the room, or be sure that the light from other sources than the candles falls equally on both sides of the screen. Look at the screen. If the spot seems brighter than the paper, move it towards you; if it seems darker, move the screen nearer the other light, but keep it in the direct line from *a* to *b* and perpendicular to this

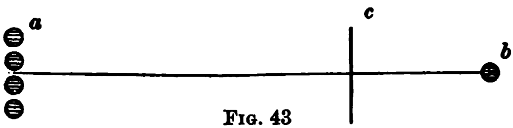


FIG. 43

line. When the spot is equally bright, viewed from either side, measure the distances *ac* and *bc*. (Care should be used that the five flames be of equal size or brightness.) How much greater is the luminosity at *a* than at *b*? If at *c* the illumination from both sources is the same in intensity, how great has been the decrease in that from *a* as compared with that from *b*? Compare this decrease of intensity with the relative distances as measured. State the law for the variation of intensity in illumination.

SHADOWS

234. When the sun is fairly low suspend a ball in full sunlight so that its shadow may be traced for some distance. Holding a cardboard always at right angles to the long axis of this shadow, follow the latter for some distance away from the ball. Carefully describe any differences in the shadow that are observed. Does the shadow seem to increase or decrease in diameter at points farther from the ball? Does it become sharper or less distinct in outline? Do the dark portion (umbra) and the whole shaded area change in the same way, or does one gain and the other lose in diameter? Account for these things, making a diagram to help illustrate. What would be the shape of the complete umbra of this shadow?

Reflection

Law of Reflection

235. Upon a 12-inch square of cardboard (Fig. 44) draw a line *ab* 2 inches from one side. Let *o* be the middle point of this line, and draw *oc* perpendicular to *ab*. At *o*, exactly along the line *ab*, make a slit through which a small mirror (a strip of silvered glass without a frame) shall be thrust.

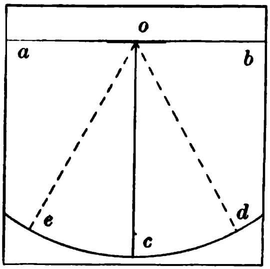


Fig. 44

Stick a pin upright at *c*. Look towards the mirror, and when the reflected image of this pin is seen exactly at *o*, mark the line along which you are looking. At what angle do the rays from *c* to *o* meet the glass ? At what angle are these rays reflected from it?

Now place the pin at any point *d* and find the point *e* at which the eye must be placed in order to see the image reflected at the point *o*. Draw the lines *do* and *eo* and state what each line represents. Now measure the angles *dob* and *eoa*. State what each angle represents with regard to the rays and compare their magnitudes with each other.

Take any other points, as *d*, and repeat. Write the law of reflection from plane surfaces.

Reflection from Smooth and Rough Surfaces

236. Secure a good mirror of fine plate glass; also a looking-glass of the poorest quality. Carefully feel the surfaces, noting any difference that is discovered. Now look at your reflected image in each and describe the difference in these images. Explain this difference. (Assume

that the reflecting surfaces in both glasses are like those you could feel of.) If the irregularities of the poorer surface were to be made much more acute and were greatly increased in number, what would be the effect upon the rays falling on the surface? Looking at that surface, what would be seen ? Name such a surface.

Reflected Images

237. Look at your own image in a plane mirror. Stand near enough to touch the glass and perform the following experiment without moving the head in the least. Close the left eye and stick a bit of wet paper on the spot where you see the image of the right eye when looking with the right. Close the right eye and stick a bit of paper where the image of the right appears when viewed with the left eye. Still without moving, let somebody standing beside you mark where your right eye seems to him to be reflected. Do these points coincide? How many different images of the eye do you think may be seen upon the glass ? What determines the particular one of these that any eye shall see ?

238. Stand before a mirror so that you can see your image. At what angle do the rays (by which you see this image) strike upon the glass and also leave it? Now move to one side so that you cannot see your image; then let somebody stand in such a place that you can see his image. Can he also see yours? Find, by consulting, just where upon the glass each sees the other's image. Repeat the exercise in various positions with regard to the mirror.

Reflection from Concave Surfaces

239. Fasten a concave mirror in some convenient support; also fasten a white card in the clamp of a ring stand. Place the mirror where it will reflect the sun's rays, and so adjust

the card so that these reflected rays will describe upon it a perfect circle. (The proper position may be found by experiment.) Now, keeping the card in a plane parallel to that in which it lies, move it till the spot is at its least size. The sun's rays striking the mirror may be considered parallel rays. How describe the rays after reflection from the concave surface? Draw a diagram showing this. Name the spot where the rays meet after being reflected. Measure very accurately the distance from the center of the mirror to this spot; call this the focal length of the mirror.

240. Place a candle flame or lamp flame at the principal focus of the concave mirror. Darken the room, and by the use of some white screen note the cross section of the reflected beam at different points. Describe this reflected beam. (Note that the flame, being large, is not entirely at the principal focus; hence the resulting reflected rays are not strictly parallel.)

Refraction

241. Hold a pencil with about 3 inches of it beneath a water surface. Describe its appearance. Is the pencil really changed by placing it in water? Have the light waves by which you see it been changed? If so, is it those that are entirely in air or those that come through both water and air that are changed?

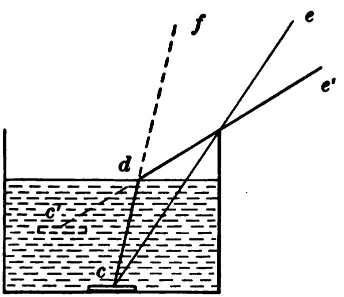


Fig. 45

242. Place a penny in the bottom of a cup. Look at this and then lower the head till the coin can just be seen over the edge of the cup. Draw a diagram, as Fig. 45, showing by a line *ce* the direction of

rays from the coin to the eye. Now lower the eye to a point e' from which c cannot be seen. Without moving the eye or the cup pour water into the latter till the coin can again be seen. Draw c' where the coin seems to be. The rays by which it is seen must therefore come to the eye *as if* their direction were $c'e'$; at least the portion of them that is in the air moves to the eye in the direction de'. But since the waves by which the coin is seen must have come from the coin, the rays which move towards the eye from d must have come from c through the water. Draw cd; then note the path of the rays (cde') by which the coin may be seen from e'. Project cd to f to show the direction of these rays before the water was added. What effect had the use of the water upon these rays? At just what point is their direction changed? Compare the two media (water and air) as to density.

243. Draw a heavy black line on a white card, and over it (but not covering its full length) lay a piece of clear plate glass. Look at the line in such a way that the rays from the line to the eye make acute angles with the face of the glass. Note the line near the edge of the glass; the rays from it to the eye, that pass through air only, may be thought to come in a straight line. What is true of those rays that come partly through glass and partly through air? Compare the densities of the two media.

Now look at the line so that the rays from it to the eye pass at right angles to the glass surface. Does the line now appear broken? Repeat, varying the position of the eye. What sort of angle must the rays make with the surface between two media in order that they shall be refracted?

244. About 10 feet away and about on a level with the eyes place a lighted candle. Looking towards this, hold a glass prism a few inches before and above the eyes, one

face (*bc*, Fig. 46) being horizontal. Look in the face *ab* and move the prism about till the candle flame may be clearly seen through this face. (Practice may be necessary.) When this position is found, hold everything still until you have noted, clearly enough to record it on paper, the direction of

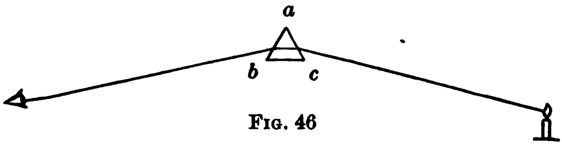


FIG. 46

the rays from the flame through the prism to the eye. Make a diagram of this. Through what media, as to density, do the rays successively pass? At what angles? How is their direction changed with reference to the base *bc* on entering and on leaving the prism?

Lenses

245. Draw diagrams of a convex and a concave lens, showing the relation of these to prisms. With the results of Ex. 244 in mind, draw parallel lines meeting the face of each lens and show how these would be refracted.

246. Hold a convex lens exactly perpendicular to the sun's rays so that the spot of light made on a white card held behind the glass and parallel with it will be circular. Move the card away from the lens. What effect has this upon the circular spot of light? Move the card till this spot is at its smallest size. How much of the light that fell upon the glass now falls upon this point? Carefully note and measure the distance from the center of the lens to this spot; this is the focal length of this lens.

Move the card still farther from the glass and determine what becomes of the rays after passing the focus. Show all this in a diagram.

247. Make a box in which a lamp may burn, but light-tight except for the chimney hole above, draft holes near

the base on the back, and one small hole ($\frac{1}{8}$ inch in diameter) in the front just level with the flame. Place the convex lens in such a position that the source of the light waves falling upon it through this hole shall be at approximately the principal focus of the lens. (The results of the preceding exercise may help determine this.) With this apparatus adjusted and the lamp lighted, darken the room and note the beam of light after passing through the lens. This may be done by means of a movable screen. Describe the beam. If the source of the rays could be exactly the principal focus, what would be true of them after passing through the lens? Show this by a diagram.

248. With the device of Ex. 247 move the lens in a straight line away from the flame so that the rays will come from beyond the principal focus. With the screen explore the refracted rays to determine the shape of the beam. Describe the latter. When the source of rays is beyond the principal focus, what is true of the refracted rays? Show this by a diagram. In Fig. 47 *f* is the source of the rays, *l* the lens, and *f'* the point toward which the refracted rays converge; *f* and *f'* are called conjugate foci.

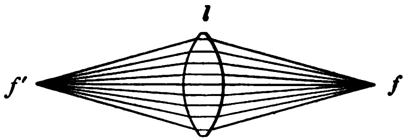


Fig. 47

249. Repeat Ex. 247, but with the source of the rays placed nearer the lens than its principal focus. Again explore the refracted beam and make a diagram to illustrate the result. If rays fall upon a convex lens from a point nearer it than the principal focus, what is true of these rays upon being refracted?

Note. The principle of Ex. 247 is applied when it is desired to project light in a particular direction with the greatest intensity, as in projection lanterns, headlights, search lights, lighthouses, etc. The

principle of Ex. 248 is used when images are formed by means of convex lenses, as in cameras or the eye, while that of Ex. 249 enables us to magnify images as with a microscope.

Note that many of these exercises calling for a darkened room may be done in a room that is not absolutely dark, provided care be exercised to prevent the interference of light from outside sources with the results that are sought.

Formation of Images; Camera

250. Get a box about 6 inches in length and width. In the middle of one side cut a hole 1 inch square and cover this with a visiting card in which has been made a large, smooth pin hole. Remove the opposite side and in its place put a screen of ground glass or of oiled paper. Have the box light-tight except for the pin hole, and if convenient paint it black inside. This is a pin-hole camera.

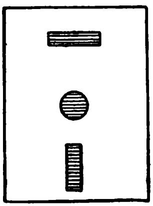


FIG. 48

From the face of the lamp box (Ex. 247) cut a vertical strip 5 inches long and 1 inch wide so that its center will be opposite the flame. In a cardboard cut holes as in Fig. 48, 2 inches apart. Over the card stick a thin oiled paper; then fasten the card over the vertical hole in the box. When the lamp is lighted the front should show only the three bright spots.

In a darkened room direct the pin hole toward these lighted spots from a point a few feet away, moving nearer or farther till an image of the spots appears on the ground glass. Draw a diagram showing the path of rays from the light spots to the screen (Fig. 49). Now direct the camera towards the view out of doors, looking into the screen. Is the picture inverted? Why?

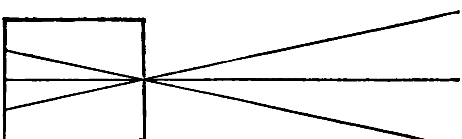


FIG. 49

Note that refraction does not play a part here; this exercise simply brings clearly to mind that images are formed by the rays from one point of an object being directed to one point on a screen, upon which point no other rays are then falling.

251. Hold a convex lens before the face of the light box (Ex. 250), parallel with it and 3 or 4 feet away. Back of this hold a white card as a screen, moving it till the image of the three spots appears clearly. Is the image inverted? Compare its clearness and brightness with the like image made with the pin hole. Make a diagram showing how the rays from one spot go to the lens and are refracted to the screen (Fig. 50). Compare this with the one made in Ex. 250 and state the advantage of using the lens instead of the pin hole to form images. Compare the result of this exercise with Ex. 248.

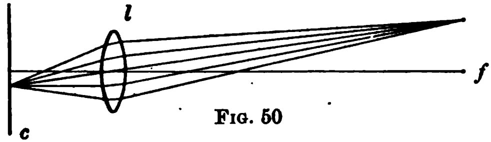


Fig. 50

252. Replace the card on the light box (Ex. 250) with one in which a vertical arrow has been cut and on which the oiled paper has been pasted. Bring the image of this sharply on the screen with the lens, as in Ex. 251. Carefully note the distance from the lens to the screen. Now move the lens a few feet farther from the light box and again bring the sharp image on the screen. Note the distance from lens to screen and compare it with the one previously noted. As the distance of the object from the lens increases what is true of the focal distance of the image?

253. Standing in a room facing the windows, by use of the lens make an image of the windows and the view to fall upon the card. Is this image inverted? How does it appear when "out of focus"? How can it then be brought to focus again? Where, in Fig. 50, might the card be held to bring the image out of focus? What necessary part of a

camera is lacking in the device used in this exercise (lens and screen)? Of what use is it? Why are these camera boxes blackened inside?

Magnified Images

254. Holding a convex lens near the eye, look through it at some object (as the hand) held at the focal distance away from the lens. Move the object to and fro, noting the effect upon the size of the image. When the image is largest note the distance of the object from the lens. Is it nearer or farther than the principal focus? (See Ex. 249.) Is the magnified image inverted?

Color

255. Arrange a prism so that a beam of sunlight will come through a slit and fall upon one of its faces, as in

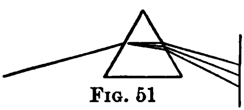


Fig. 51

Fig. 51. Place a white card so as to show the spectrum of this light. Describe this spectrum, naming the colors in order as they are seen. Clearly the beam entering the prism is of white light. Were all these colors included in it? How were they separated by the prism? Which waves were bent the most? Which were bent the least?

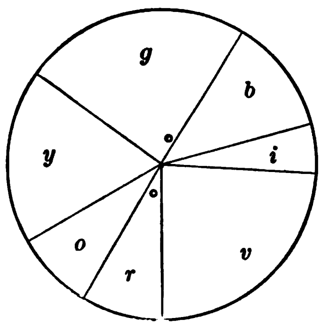


Fig. 52

256. Upon a circular cardboard 7 inches in diameter paste pieces of colored paper in about the proportions of Fig. 52, using regular prismatic shades of red, orange, yellow, green, light blue, dark blue, and violet. One half inch each side of the center make a small hole through which a stout string may be

passed and tied. Any boy will know how, by twisting this double string, the card may be rapidly rotated. What effect is produced when these colors are thoroughly blended?

257. Cards like that of Ex. 256 may be made to show the combined effect of complementary colors, as yellow and blue, red and green, etc. The proper amount of each color may be found by experiment.

258. Exclude the light except for a beam of sunlight through a small hole. Cover this hole with a red glass. Now look at several pieces of colored paper or cloth, the true color of which you have no way of knowing, mark each by a number, and on another paper write each number and the color that the piece appears to be. Now examine these in daylight, comparing with your list. Account for the results. What waves pass through red glass?

259. At the base of a Bunsen burner make a dust of some salt of potassium, sodium, barium, strontium, or copper, or scrape a lithia tablet (containing lithium). Note the effect upon the flame as these metallic compounds become luminous in it. This may indicate in a general way how the analysis of flames is possible and significant.

ELECTRICITY

Conductors and Nonconductors

260. Make an electroscope (Fig. 53) by passing a copper wire through the rubber stopper of a flask and hanging over it, within, a strip of gold leaf or aluminum foil.

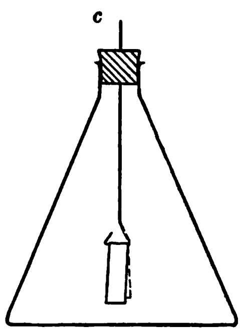


Fig. 53

Make a proof plane by fastening a bright penny across the end of a glass rod by means of sealing wax.

Charge one end of a stick of sealing wax (6 inches or more in length) by stroking it with a woolen cloth. Do this not farther than 3 inches from the end. At once touch the wire of the electroscope at *c* with the charged end of the stick. State the result. Now discharge the electroscope by touching the wire; then touch the wire with the other end of the wax. Does the charge developed upon one part of the wax stick seem to have spread over it?

Again stroke the same end of the wax, touch it with the proof plane (the penny), holding this by the glass handle, and touch the wire *c* with this. Does the charge seem to have spread to the copper penny? Discharge the electroscope and fasten a copper wire 1 foot long to *c*. Again charge the wax and then the proof plane and touch the far end of the copper wire with the latter. Note the leaves. Does the charge seem to spread over the wire?

Use other things in place of the 12-inch wire, — brass wire, wood, glass, iron wire, paper, cloth, zinc, etc.

NOTE. The substances over which a charge immediately spreads are called conductors. Over some substances the charge does not spread, but remains where it was developed; these are nonconducting substances. The charge upon the latter, being at rest, is called static electricity, and this may give rise to certain phenomena, as the following exercises indicate.

STATIC ELECTRICITY

261. Stroke a glass rod with a silk cloth; then bring each near bits of paper. Do you think the glass and the silk are electrically charged?

Repeat the foregoing, using sealing wax and a woolen cloth.

Repeat, using a rubber comb and dry fur. Passing the comb through the hair (if the latter is dry) may develop electricity.

The nonconductors, upon which electric charges do not spread, may be charged in many simple ways. Thus a cat's fur and the hand that strokes it become charged; machine belts passing through the air often bear charges of electricity; and we sometimes develop charges upon the body by shuffling over a woolen carpet.

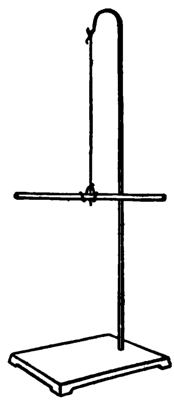


FIG. 54

262. Suspend a glass rod balanced by a silk thread, as in Fig. 54. Stroke one end of it with a silk cloth a few times; then, the rod being still, present very near to it, but not touching, that part of the silk with which it was rubbed. What happens? Now charge another glass rod likewise and bring it very near the other (suspended). Compare the result with that just recorded. Would these results seem to show that there is a difference between the charge developed upon the two bodies that rub each other?

263. Repeat Ex. 262. If the charges upon the glass and silk are unlike, how do unlike charges act towards each other? If the two rods bear like charges, how do like charges act towards each other?

264. Charge the suspended glass rod as before. Now charge a stick of sealing wax, using woolen cloth, and bring this near the rod. Does the wax bear a charge like or unlike that of the rod? Repeat, using the woolen cloth; compare its charge with that of the rod, and the facts with those shown in Ex. 262.

265. Suspend a ball of pith by a fine silk thread. Charge a glass rod and bring it near the pith ball; state the result. Does this seem to show that the pith ball is charged? If so, is its charge like or unlike that of the rod? (The charging of one body by action of the charge upon another not in contact with it is called induction.)

When the pith ball moves to the rod let it remain in contact with the rod as long as it will. What presently happens? Does the ball now seem to bear a charge like or unlike that of the glass rod? State the difference between the charge received upon one body from another (1) when separated from it and (2) when in contact with it.

266. Fill a shallow metal plate with sealing wax (melt and pour it). In the middle of a smaller metal plate (resting right side up) fasten a pill vial by means of sealing wax, for an insulated handle. This device is called an electrophorus.

Strike the solidified wax surface a few times with a piece of cat's fur; then press the metal plate down upon it at all points. Lift the plate by its handle; then bring the finger to within an inch of it and slowly move it nearer. What happens? In moving away from the wax the metal plate became charged by induction. Was its charge then like or unlike that of the wax? When the finger was near enough this charge passed off through the body; this is called a

discharge. This discharge passed to the finger through the air. What did you see, hear, or feel at that moment? What phenomenon in nature is here illustrated?

267. Electrostatic charges may be stored and accumulated by means of the Leyden jar. If an electrostatic machine is available to charge these, many interesting exercises may be performed.

Dry apparatus and dry air are important factors in the success of experiments with static electricity. Even with these success is variable.

ELECTRIC CURRENT

Voltaic Cell

268. Cut a block of wood 1 inch wide so that the part *ab* (Fig. 55) shall just fit within the rim of a tumbler, the ends resting on the rim. Upon each side of this fasten a strip of copper by one end so that it may hold a metal strip slipped between it and the wood. Drive a copper nail through each strip, *c* and *d*, into the wood.

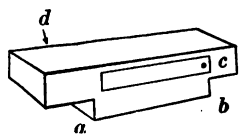


FIG. 55

Into a tumbler two thirds full of water pour a spoonful of sulphuric acid. Cut a strip of zinc and of copper, each about 4 inches by ½ inch. Slip one of these into each of the clamps on the block and lay the block upon the tumbler. The two strips should now hang in the acid solution, nearly to the bottom of the glass; but they are not in contact at any point, — this is important.

Watch the metal strips; describe what you see. Does there seem to be any difference in the degree of activity at the two plates? If so, state where it is the greater. Is this activity electrical or chemical?

Connect the posts *c* and *d* with copper wire, bare at the parts where it is wound about the nails. Note the activity

at the plates. Is it any different? If so, in what way? Is wood a conductor? (See Ex. 260.) What has been done now that was not done before the copper wire was added?

269. A galvanometer may be made by nailing upon a board, at opposite edges, two strips of wood thick enough so that a wire wound around the whole shall be clearly above a compass placed on the board. Wind insulated copper wire (about 22 gauge) in a coil of twenty-five turns across this (Fig. 56) and fasten its bare ends, one about each of two copper nails, *a* and *b*. Place a compass under the coil and turn it so that the wires and the needle will be parallel.

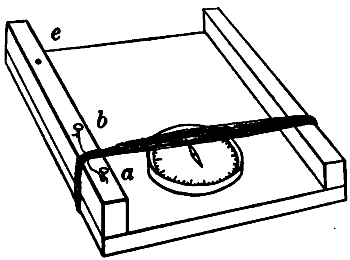


FIG. 56

Connect the posts *c*, *d* of the cell (Ex. 268) with *a* and *b* of the galvanometer respectively. What do you see that may indicate an electric current passing along the wire? When the needle comes to rest note where it is; then unfasten one wire, let the needle come to rest, and note its position. Is a current now passing along the wire? Change the wires, putting the one that was on *a* upon *b*, and vice versa; note the motion of the needle. Is there any indication that the direction of the current has been changed by this? If so, then what we call a current may be considered as somewhat of the nature of a flow or discharge from one point to another.

(If, when connections are well made, there is no deflection of the needle, more acid may be added to the cell. If the deflection is 60° or more, one wire may be led to another nail *e* and a coil of insulated wire added between *e* and *b*.)

Local Action: Amalgamation

270. Dip a fresh zinc strip into the acid solution and note the action. Now clean this strip, dip it into a dish containing mercury, and wash it over carefully with the liquid, rubbing it in till it is well covered with amalgam. Place this again in the solution and state the difference in the action. What effect do you think this might have upon the destruction of the zinc plate?

Polarization: Two-Fluid Cell

271. Connect a fresh cell, with amalgamated zinc and new copper plates, with the galvanometer, as in Ex. 269. When the needle is at rest read the degrees of deflection produced by the current. Thereafter, at five-minute intervals, make like readings and record them till there appears a marked difference in the deflection. Note the gas accumulated about the copper element in the cell.

Thoroughly dry the copper plate by heating it; then place it in a small porous cap (unglazed earthenware) into which you pour a strong solution of copper sulphate. Set this cup and contents in the tumbler and connect the copper plate as before. Again note the readings on the galvanometer and compare these with the ones previously found. Note the gas about the copper plate and compare the quantity with that observed before adding the second fluid. What effect upon the accumulation of gas has the use of the second solution? What effect has this upon the current? Why should the presence of gas around one element thus affect the current? (The porous cup serves to keep the fluids separate, but it soon becomes wet and does not interfere with the passing of the current.)

The Circuit

272. Connect a cell with a galvanometer, a bell, or any device that will show clearly whether or not a current is passing. With all connections made, trace the path of the current, beginning anywhere, say at the copper plate. Now break the complete conducting path by slipping the wire off one post at the galvanometer. What effect has this upon the current? Do you think it stops the current in the entire path? To answer this, break the circuit (the conducting path) at various points on either side of the detector. Also lift each plate separately from the liquid. In what ways can you break this circuit? Touch the plates together in the cell, all connections being made completely. What effect has this upon the current through the circuit?

273. With a cell set up and the circuit complete, cut one wire. Scrape the ends at this point till they are bare and bright; then separate them one-half inch. Is the air a conductor of electricity? Now keep these ends apart but successively connect them by means of different substances, — iron, wood, clay, copper, glass, rubber, zinc, leather, tin, cloth, paper, silver, common rocks, etc. Which of these are conductors and which are insulators? Is water a conductor? (Try it.)

NOTE. The importance of both conductors and insulators in man's controlling electricity is too evident to require discussion. Conductors permit the instant flow of electricity to distant points, while insulators are equally important in keeping it within bounds. Even bare wires are insulated by the air, and to break a circuit is practically to introduce an insulator into the path of the current.

Arrangement of Cells in a Battery

274. Arrange two cells in series, — the positive plate of one joined by a short copper wire to the negative of the

other. Run the other wires (one from each vacant post) to a voltmeter and note the indicator.

Now connect these in parallel (multiple arc) arrangement, — join the two positive and the two negative plates, and lead the other wires one from each side (positive and negative). Join these to the voltmeter. Which arrangement gives the greater driving effect (electromotive force)? Now try a single cell in place of either arrangement, note the indicator, and state how the effects of these previous arrangements compared with that of the single cell.

(Lacking the voltmeter, the galvanometer (Ex. 269) may be used. If the needle is deflected too far by the series, introduce a small coil of fine insulated wire into the circuit.)

Resistance

Internal Resistance

275. Arrange the cell connected with the galvanometer as in Ex. 269. Now lift both plates till each has just half as much surface beneath the liquid as before, and state the effect upon the current. Again lift them till they expose but one quarter as much surface below the liquid. State the effect. In general, what effect has the size (cross section) of the liquid path within the cell upon the resistance offered to the current? (A weakening of the current will indicate a greater resistance offered.)

276. Repeat Ex. 275, only vary the distance between the plates within the cell, keeping the cross section of the liquid path between them constant. What effect upon resistance offered to the current has the length of the liquid path within the cell?

Note. It will be evident, upon reflection, that a parallel arrangement of cells (Ex. 274) increases the cross section of the internal liquid path without increasing its length. Thus this arrangement lessens internal resistance.

External Resistance

277. Connect a cell and galvanometer as before, but into the circuit introduce 5 feet of No. 30 copper wire. Record the deflection of the needle. Now remove this extra piece and substitute for it a piece of the same size but twice as long. Note the needle. State the effect upon resistance of the circuit that is produced by increasing the length of the conductor.

278. Connect the cell and galvanometer, introducing the 5-foot piece of No. 30 copper wire and reading the deflection. Now add another piece of No. 30 wire, the exact duplicate of the first, joined to it and lying beside it. Make all connections carefully. This should keep the conductor the same in length, but increase the cross section at this point. What effect has the increase of cross section upon the resistance offered by the conductor?

279. Connect the cell and galvanometer and arrange to introduce into the circuit wires of different metals. Have these uniform in size and length, — say 2-foot lengths of No. 22 wire of iron, brass, German silver, copper, zinc, etc. Is there any very marked difference in the conductivity of the different substances?

Divided Circuit

280. Make a resistance box as indicated in Fig. 57. Into a board ($6 \times 8 \times 1$ inches) drive copper tacks (*a*, *d*, *e*, *f*, *g*) not quite to their heads. Join *a* to *d* by No. 22 copper wire. Then starting at *d* with No. 30 insulated copper wire, make three coils as shown, each coil containing about 27 inches of wire; this must be bare where it is wound about each tack. Now make a flat stick that shall turn upon a tack *c* as a pivot; along the whole lower face of this fasten a strip of sheet copper. Also fasten a strip of this to the board by the copper tacks *b* and *c*. Drive *d*, *e*, *f*, *g* down till their heads are just above the board surface. The whole should

now be found so arranged that a complete conducting path will lead from *b* to *a* when the copper-faced stick rests upon either *g*, *f*, *e*, or *d*. The coils simply add resistance to the path, more as the stick is moved from *d* to *e*, to *f*, to *g*. Look it over till this point is clear.

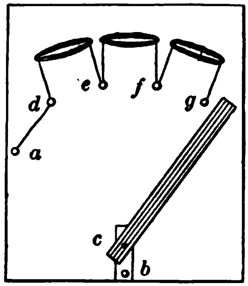


FIG. 57

Arrange two cells of "dry battery" in series. Lead one wire to a toy motor; then from the other post of the motor to the other binding post of the battery. Put the resistance box into a shunt by leading a wire from this second binding post of the battery to *a*; then another from *b* to the first post of the battery. Now the circuit is divided, one branch being through the motor and the other through the resistance device.

Put the stick on the tack *d*. Does this introduce much resistance to this branch? Now move it to *e*. Does this add to or reduce the resistance in this branch? What effect has this on the motor? Move the stick from one to another button, noting the motor. State the general effect upon the strength of current in one branch of the circuit when the resistance in the other branch is increased or lessened.

NOTE. The principles of resistance are important in the control of electricity. Ex. 280 shows how the current in one division of a circuit may be affected by variations in the "load" carried upon other divisions of the circuit, i.e. by the switching on or off of lamps, motors, etc.

ELECTRICAL EFFECTS

Electrolytic Effect

281. Solder a 2-foot copper wire (No. 22) upon each of two strips of sheet copper (about 1 × 3 inches). Connect

one wire to each of the vacant binding posts of a battery, — two dry cells connected in series. Into a tumbler two thirds full of water pour a few drops of sulphuric acid, — this to make the liquid conduct the current better. Now put the two copper strips into the liquid, being careful that they do not touch each other. All connections being made, the current should flow through the water. What do you observe that seems to be a result of this? Water is made up of hydrogen and oxygen, two gases; there is twice as much hydrogen as oxygen, by volume. Try to explain what the current does to the water. Does the quantity of gas at one plate seem to be greater than at the other? Do you think both gases are given off at both plates or one at each?

NOTE. The electrolytic effect is useful in breaking down certain chemical compounds to get out some of their constituents. Its use in plating will be taken up later.

Thermal Effect

282. Connect two dry cells in series and attach two line wires, each about 2 feet long. Scrape the ends of these wires bare. To one of these ends connect a fine iron wire, about No. 30 and 4 inches long. Holding the line wires (do not hold the iron wire), bring the end of the free copper wire into contact with the free end of the iron wire. Gradually move it along the iron towards the other copper wire, lessening the distance the current has to move along the iron wire. What do you observe? Does this small iron wire offer much resistance to the current? Compare the resistances offered by the copper and the iron wires. Compare the corresponding heating effects of the current.

NOTE. This effect is very useful. Heaters for electric cars, electric ovens, various household devices, and electric lights, both incandescent and arc, depend upon this principle. In the electric furnace temperatures have been reached that were hitherto unknown upon earth.

Physiological Effect

283. The current from a small induction coil or "medical battery" may be passed through the body by grasping the proper handles. Slight shocks may be experienced from a Leyden jar or from a small spark coil, but it is best to do this only under the direction of the instructor.

Magnetic Effect

284. Place a compass on the table. Above and parallel to the needle hold the wire leading from a single cell, and connect the circuit. State the effect upon the needle. Break the circuit. What is the result? Would the results seem to show that a current-bearing wire may give rise to magnetic force? Is this effect permanent or does it cease when the current ceases?

285. Through the center of a cardboard square run a copper wire, and connect this with two cells that will give a current of fifteen amperes or more. With the circuit closed sprinkle iron filings on the card and tap the latter gently. Place a small compass on the card in various places, noting the position taken by the needle. Describe this position with reference to the lines assumed by the filings. Do the filings and the compass seem to show that there is magnetic force operating when the current is on the wire?

Fig. 58

286. Wind an insulated copper wire about a pencil, as in Fig. 58. Remove the pencil; then attach the wire to a cell so that a current will pass through it. Bring one end of this current-bearing coil near one end of a compass needle (the other end being directed away from the needle) and state what occurs. Let the needle come to rest, reverse the coil, and

present the other end of it to the same end of the needle. What now occurs? Magnetic force seems to act in what two ways?

Again, with the needle at rest, hold the coil at right angles to the direction of the needle and bring it towards one end of the latter so that its middle point will be nearest the needle. Compare the action of the compass now with that observed when either end of the coil approached it.

NOTE. This important effect will be considered more fully in the exercises following. The coil as used in Ex. 286 is called a solenoid.

MAGNETS

Electro-Magnet

287. Coil an insulated copper wire about a soft iron nail, making about fifty turns. Pass the current from a single cell through this coil, having the wire so arranged that the circuit can be quickly made or broken. Test the magnetic effects of this by trying to lift tacks or iron filings. With the circuit broken, bring one end very near a tack; holding it there, connect the circuit. Lift the tack on the magnet and then break the circuit. Does the nail act as a magnet when there is no current in its coil? How long (after making or breaking the circuit) is required for the core to become magnetized or demagnetized? Is it necessary to have the copper wire insulated? Explain why.

Slip the core out from the coil and try the latter at picking up things, as was done with the whole. Is the solenoid as effective without the iron core?

NOTE. Electro-magnets are of great importance. Their wide usefulness is due in part to the rapidity with which they become magnetized and demagnetized. The separate strokes of a call bell and the clicks of a telegraph instrument are each accompanied by a magnetizing and demagnetizing of an electro-magnet. Enormous magnets of this sort are used in lifting and carrying heavy masses of iron, and in like work.

Permanent Magnets

288. Get a rod of steel as near the size of the iron nail as possible and wind an equal number of turns of wire about it (Ex. 287). Pass a current through the coil. Does the steel core become magnetized? Let the circuit remain closed and, as the current continues to flow through the coil, test the strength of the magnet from time to time. Does it seem to increase in strength for a time? (If little effect is noted, add cells to the battery.) When the core is magnetized, break the circuit. What effect has this upon the magnet? Compare the magnetizing and demagnetizing of the steel rod with that of the soft iron. Remove the steel core from the coil. Is it still a magnet? Try it later from time to time. Jarring the steel core, as by tapping it slightly with a hammer while the current is flowing, may help the process along.

289. Let the current from at least two dry cells pass through the coils of an electro-magnet while you draw a common steel needle several times across one end of the iron core, drawing it from eye to point and always in the same direction. Test the needle by trying to pick up iron filings. Can you lift another small needle with it? State two ways in which permanent magnets may be made.

290. Test a magnetized needle; then heat it to red heat and let it cool slowly. Again test it for magnetic properties. What effect has this heating upon the magnetic property of the permanent magnet?

NOTE. Besides its important use as a compass needle, the permanent magnet is of service in small dynamos ("magnetos") and in telephone instruments.

Magnetic Field

291. Balance a square of cardboard across the ends of a horseshoe magnet. Sift fine iron filings evenly over the card; then tap it lightly. Do the filings arrange themselves as if

acted upon by some force associated with the magnet? Indicate this arrangement by a drawing. The lines along which the filings lie are known as lines of magnetic force. The whole region within which these lines can be detected is called the magnetic field.

292. Lay a bar magnet upon the table and lay upon it a cardboard somewhat longer and much wider. Sift iron filings upon this and jar it, noting the lines of force. Make a drawing of the field as it appears in this case.

NOTE. The field may also be explored with small compasses, the directions of the needles being noted. Electro-magnets may be used as well as the permanent type, and other sections of the field may be observed.

Magnetic Poles

293. Lay a small bar magnet down in iron filings; then lift it and note the filings that cling to it. Where are these most numerous? Are there any at the middle? Do they increase gradually as the ends are approached, or abruptly? The ends of the magnet are known as its poles. What is the object of making a magnet in horseshoe form, i.e. its poles near together?

294. Magnetize a large steel needle and lay it upon iron filings, as above. Does it seem to exert any attractive force at its middle point? Now break the needle exactly at this point and test the freshly broken ends. Do they seem to exert magnetic force? Do you think, then, that the needle is less magnetized at its center, or that the magnetic property is shared by all parts of the needle but most effective at its poles?

Magnetic Action

295. Look at a compass needle (this is, of course, a magnet) and note which pole points northward. Disturb it several times, each time letting it come to rest and noting which pole is northward. Is it the same one every time?

Bring one pole of a bar magnet towards the north-seeking pole of the compass needle and state the effect upon the latter. Now reverse the bar magnet, presenting the other pole of it to the same (north-seeking) pole of the compass. State the effect. Do the two poles of the bar magnet have the same effect upon the one pole of the needle?

Now use the same (either) pole of the bar magnet, presenting it first to one end and then to the other end of the compass needle. State the results. Does there seem to be a difference between the two poles of a magnet in their manner of acting towards another magnetic pole?

296. Get two like horseshoe magnets, — those used as toys. Find by experiment with the compass needle the like poles of these (e.g. find the pole of each that repels the north-seeking pole of the needle). Mark these like poles in some way; also look to see if there is not some mark placed on the magnets by the maker that will corroborate what you have determined.

Lay one magnet on the table and bring the other so that its ends will touch, like poles being in contact. Draw one magnet away. Does the other follow? Now turn the second magnet over so as to bring unlike poles into contact. Draw one away. Does the other follow? Do like poles or unlike poles attract each other?

297. Bring one pole of a bar magnet near the north-seeking pole of the compass needle. If it attracts the needle, is this pole like or unlike that of the needle? (See Ex. 296.) In any case you can now tell which pole of the bar is north-seeking (positive). Therefore bring that pole (the positive) near the like pole of the needle and observe the effect of like poles upon each other. State this effect. Now bring the other (negative or south-seeking) pole of the bar near the other (south-seeking) pole of the needle,

and see if the above statement applies also to those poles of like sign. Does it? State, then, the whole behavior of magnetic poles towards each other. This effect was not observed in case of the two horseshoe magnets because the repelling effect is not great enough to move the magnet along the table.

298. Lay the horseshoe magnets upon the table as before, like poles in contact. Move them apart one inch. Cover them with a cardboard and sift iron filings over the card. Note and draw the positions of the lines of force.

Repeat, laying the unlike poles opposite each other.

299. Try lifting various substances with a magnet,— pieces of wood, glass, copper, iron and steel, zinc, tin, nickel, silver, brass, etc. Which of these are attracted by the magnet? Are these attracted with equal force?

300. Try the effects of the separate poles of magnets upon unmagnetized pieces of iron or steel. Tacks may be used, a fresh one for each trial. State the action of the poles towards unmagnetized iron or steel.

NOTE. The differential action of the magnetic poles — the attraction of unlike and repulsion of like poles — makes possible the continuous rotary motion of the electric motor. Its importance is therefore evident.

CURRENTS BY INDUCTION

301. Make a sensitive current detector by suspending a coil of wire between the poles of a horseshoe magnet, as in Fig. 59. Use No. 26 insulated copper wire and make about thirty turns. Inclose this in a box, the magnet being upright, as in the figure, and put a glass front on the box. The coil must be free to turn with ease. Fasten a broom spill between the coils for an indicator.

Continuous with this coil fasten a like wire which is made into a coil of five hundred turns, both coils being in complete circuit, as in Fig. 59. Now bring the outside coil

suddenly into the field of a strong magnet, noting the indicator of the current detector. What do you observe? Now move the coil out of the field and state the effect upon the indicator.

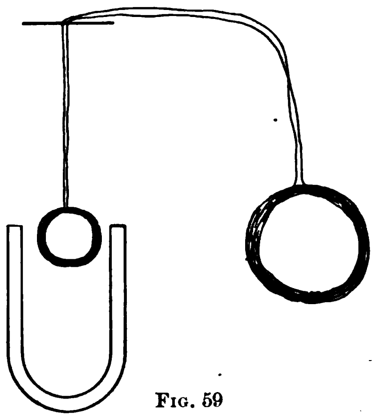


Fig. 59

Make various tests, moving the coil through the field to determine whether a current passes through the wire while the coil is simply within the field or while it is moving through the field. State your conclusion.

Try to determine whether the current moves in the same direction while the coil is being moved away from the magnet as while it is being moved towards it.

Note. The principle here illustrated is the one whereby we are able to generate strong currents by means of the dynamo. It is applied also in the induction coil and the transformer. Methods of varying the intensity of the magnetic field and the alternating nature of the induced currents may be studied and further illustrated if an induction coil is available.

Ohm's Law

Use of Varying Resistance

302. Arrange two cells of "dry battery," a toy motor, and the resistance device of Ex. 280, all in series, so that the whole current will pass through the motor and the resistance device. Move the switch to the button *g*; let the motor run till it has reached a constant speed and then successively move to *f*, *e*, and *d*, stopping likewise at each one. As this is done, does it increase or lessen the resistance of the circuit? State the effect of this upon the motor.

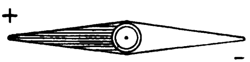
Note. This principle is important in the control of currents. The current to supply a motor is admitted to it gradually by means of some such resistance device, — e.g. the controller upon electric cars. The law is to the effect that the strength of current equals the electromotive force divided by the resistance. In this case the resistance has been varied, and the variations of the motor show changes in the E.M.F. of the current passing through it.

Various exercises for showing this relation (expressed in Ohm's Law) may be easily devised where instruments are available for measusing volts and amperes and for placing known resistances in the circuit.

Some Uses of Electricity

Electric Motor

303. Use a bar magnet and a compass, or better, a magnetized needle on a pivot but not incased. Suddenly bring the – pole of the bar near the + pole of the needle, in a position as shown in Fig. 60. The needle will move towards the bar. Just before it reaches the nearest point (i.e. while still moving) quickly reverse the bar, presenting the + pole of it at the same spot. The like pole of the needle will, by this time, have swung past that point, so that the magnet will only keep it going. Soon the – pole of the needle will come into the field of the + pole of the bar and move towards it. By carefully timing the movement the bar may be again reversed as before; and this may be continued indefinitely, imparting to the needle a rotary motion. State, in order, the four separate actions (pulls or pushes) which bring about this rotary motion.



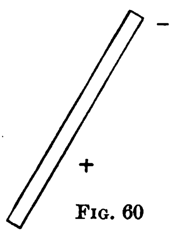


Fig. 60

304. Pass the current from a single cell through the electro-magnet made for Ex. 287. By means of a magnetic needle determine which ends are the positive and negative

poles of the electro-magnet. Now reverse the connections of the latter so that the current will pass through the coil in the opposite direction. What effect has reversing the current in the coils upon the poles of the magnet?

305. Run a toy motor by the current from a single strong cell. Note the field magnet (stationary),—its coils and cores, and the position of the poles of the latter with reference to the moving part. With a magnetic needle determine the positive and negative poles of the field magnet. Stop the motor and study the winding of its coils and its armature. (Fig. 61 may be of some help in this). Note the coils and the cores of the armature. Note the brushes *m* and *n*, whereby the current is led through the armature; also note the separate segments of the commutator *c*. Trace the course of a current through brushes, commutator, and armature coils, to discover how the direction of the current is reversed in the latter. (In a common type of toy motor there are three coils on the armature.) Study this till you see clearly how the principles of Exs. 303 and 304 are applied in the motor.

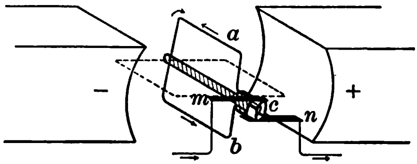


FIG. 61

Does the same current supply both the field coils and the armature coils? Are these two sets of coils in series with each other or in separate shunts? Do you think the direction of current in the field coils alternates, as in the armature? Do you think the motor would be reversed if the current ran through it in the opposite direction? After answering, try it by connecting the line wires to the other binding posts. Why is this? How could the motor be reversed?

NOTE. The principles of Exs. 303 and 304 apply to motors in general. The rapid reversal of the poles in the armature, an essential

feature of the motor, may be accomplished by a device upon the motor itself (the commutator) or by supplying an alternating current. The motor used in Ex. 305 is of the former type and uses a direct current. The other type requires no commutator.

Electric Call Bell

306. Connect a common call bell with a single cell. Hold the hammer away from the bell (i.e. against the contact point of the screw *c*, Fig. 62) and test the poles of the magnet to see if they are now magnetized. Then hold the hammer against the bell (breaking the contact at *c*) and see if the magnet will now hold a tack. (If a compass is used as an indicator, enough magnetism may remain in the cores to disturb the needle slightly, even when the current is off.) Trace the course of the current through the instrument, noting at what point the circuit is alternately made and broken, and by what means. When the circuit is made what is true of the cores? From this point describe what follows in the action of the bell.

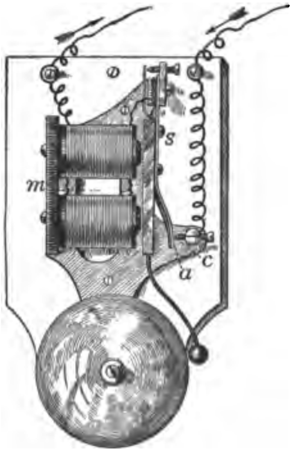


FIG. 62

NOTE. Not only call bells and buzzers but various make-and-break pieces, or "vibrators," apply this principle. The latter are used in connection with induction coils to rapidly interrupt the current in the primary coil.

Electric Telegraph

307. A simple telegraph sounder may be made by fastening an electro-magnet upon an empty crayon box, as *m*, Fig. 63, and its armature upon a stick, as *a*, above it.

Slightly notch the stick so that it will rest upon a strip of "tin" (*t*) tacked upon the end of the box. On the other end of the box fasten a long screw by staples so that when the stick rests upon *t* and the screw the armature will barely clear the magnetic poles. Also fasten a wire loop (*l*) above this, to prevent *a* from being raised more than $\frac{1}{8}$ inch above *m*. To the end of the stick, projecting an inch beyond *t*, fasten a rubber band which will hold the stick up against *l*. Run wires from *m* to a single dry cell, and break one wire to introduce any convenient "key" to make and break the circuit speedily. Adjust the rubber band *b* so that it will allow *m* to pull the stick down firmly but will lift it up with equal ease when the current is cut off.

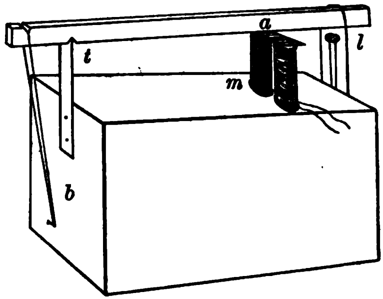


FIG. 63

NOTE. As this device involves no new principles, its operation should be clear as soon as it has been made. The box serves as a sounding board to intensify the sounds made by the stick. Such a difference will be observed between these two sounds that with a little practice the dots, dashes, and space intervals of the Morse code may be apparent.

Electroplating

308. Make a strong solution of copper sulphate in water. Arrange two strong cells (15 amperes) in series. To the wire leading from the carbon plate fasten a strip of sheet copper, making a good metal contact. Thoroughly clean a smooth iron nail and fasten this likewise to the other line wire. Place the nail and copper strip in the copper sulphate solution, being sure that they do not touch each other. After

a few minutes remove the nail, allow it to dry, and polish it by gentle rubbing with a chalky blackboard eraser. State the result. What electric effect is applied here?

Through which piece, copper or iron, did the current enter the solution? Call this the anode and the other the cathode. Upon which is the metal deposited? Now substitute a fresh nail and reverse the metals, making the iron the anode. Does it now receive a deposit of copper?

NOTE. The direction of the current is taken as that in which the positive electricity flows, which is from carbon (or copper) to zinc in the wire outside the cell, and from zinc to carbon within the cell.

For nickel plating a solution of nickel ammonium sulphate may be used.

Incandescent Electric Light

309. Into the circuit with two strong cells in series introduce about an inch of No. 30 iron wire, the circuit being open meanwhile. Close the circuit and note the wire. What happens? Does the iron wire offer much or little resistance as compared with the copper line wires? (If the wire does not glow, shorten the iron portion of the circuit. Be sure not to handle the latter while the circuit is being completed.) Examine an incandescent lamp, noting the filament in the bulb.

APPENDIX

Table of Approximate Equivalents

1 inch	= 2.54 cm.	1 cu. in.	= 16.3871 cm^3.
1 foot	= 30.48 cm.	1 cu. ft.	= 0.02832 m^3.
1 yard	= 0.9144 m.	1 quart	= 0.09464 l.
1 mile	= 1.60935 km.	1 gallon	= 3.7854 l.
1 sq. in.	= 6.4516 cm^2.	1 grain	= 0.064799 g.
1 sq. ft.	= 0.0929 m^2.	1 ounce (av.)	= 28.3495 g.
1 sq. yd.	= 0.83612 m^2.	1 pound (av.)	= 0.4536 kg.

Table of Approximate Specific Gravities

The following table is given only as an aid in making general comparisons. Nearly all the substances here listed have various specific gravities, according to the kind, purity, temperature, etc. Particularly among woods, minerals, and manufactured products there are wide variations. For accuracy it is necessary to consult tables that state in detail the variety of the substance and the conditions under which its specific gravity was obtained. The figures here given are fair averages.

Alcohol	.8	Ice	.9
Aluminium	2.7	Iron	7.2
Ash, white	.77	Lead	11.4
Butternut	.57	Maple, hard	.64
Brass	8.4	Marble	2.7
Chestnut	.52	Mercury	13.6
Coal, hard	1.8	Oak, white	.85
Copper, wire	8.8	Pine	.50
Cork	.2	Platinum	21.2
Dogwood	.81	Poplar, Lombardy	.40
Ebony	1.2	Quartz	2.7
Elm	.58	Sea water	1.03
Ether	.7	Silver	10.5
Glass	2.8	Spruce	.55
Glycerin	1.2	Sulphuric acid	1.8
Gold	19.36	Tin	7.3
Granite	2.7	Witch hazel	.78
Hickory	.95	Zinc	7.1

Laboratory Work

This manual may be used in different ways, as the teacher may desire. The author has conducted this work with laboratory divisions of about twenty students each. The material is arranged upon tables, with numbered cards to indicate the number of the exercise for which each group of material is intended. The class performs the indicated work, answering the questions and making the required observations in a notebook. No time is spent in purposeless writing. Material is cleared away when all members of the class have finished the exercise, and enough is always laid out in advance to supply everybody in the division with work for the period.

Manipulation

To cut glass tubing, scratch it transversely with the edge of a triangular file. Grasp it with both hands, the thumbs just meeting at a point on the tubing just opposite the scratch. Hold the tubing so that the scratch is away from you; then gently push with the thumbs and pull with the fingers.

To finish the cut ends of tubing, hold them in the outer part of a flame and heat till they just begin to glow, turning the tubing steadily to heat all parts equally. Avoid heating long enough to contract the ends.

To close glass tubing, proceed as directed above, but continue heating till the tube is completely closed.

To bend glass tubing, heat it over a fish-tail burner if possible, turning it steadily in the fingers till all sides of the tubing, at the desired point, are thoroughly softened. The tube can then be bent into any reasonable form. Rapid cooling will now make the tube very brittle at this point; cool it by lifting slowly up through the flame and beyond.

Capillary tubes may be drawn, or delivery jets made, by heating the tubing as directed above. When it is soft remove it from the flame and immediately stretch it out, drawing the ends apart with a steady pull.

Stirring rods may be made by closing one end of a small glass tube. Practice is needed before the best results can be expected.

Always remember that hot tubing does not cool immediately; be careful about touching it or laying it upon things that will burn.

Two-hole rubber stoppers may be made to serve as one-hole by plugging with a bit of closed glass tubing. Remove the plug as soon as you are through using the stopper.

Material

Below is a list of material called for by the exercises. Some of this will have to be bought from a supply house and some may be had from local stores. Some pieces can be made without much difficulty or expense, and still others will not be desired by some teachers. For obvious reasons no effort has been made to anticipate individual needs or desires. Some guide is offered, however, to those who want to buy material.

In column A is indicated the approximate number of exercises requiring a piece, or in some cases the number of the exercise may enable the teacher to determine quickly whether or not he desires the material.

In column B the number of pieces of material suggested is based upon the author's experience in conducting a laboratory course with these exercises, the number of students in the laboratory at one time being less than twenty-five.

	A Exs. needing it	B Amount to buy
6-inch test tube	11	24
8-inch test tube	12	24
4-inch test tube	Ex. 208	3
Tumbler (common glass)	45	15
Glass tubing, 6 mm. diameter		5 lb.
Glass tubing, ¼-inch diameter		½ lb.
Glass tubing, capillary bore		6 ft.
Thistle tube, 6 mm.	6	6
Stirring rod, small, glass	4	3
4-ounce wide-mouth bottle	4	6
8-ounce wide-mouth bottle	2	2
Battery jar, glass cylinder, 6 × 8 inches	16	6
Beaker, glass, 100 cc.	2	2
Watch glass, 2-inch diameter	3	24

	A Exs. needing it	B Amount to buy
Graduated cylinder, 50 cc.	5	2
Graduate, 1-ounce	1	1
Student lamp chimney, size of Macbeth No. 48	10	4
Chemical thermometer, 0–215° F.	15	6
Chemical thermometer, 0–215° F. & C.	3	1
Hydrometer jar	2	1
Erlenmeyer flask, 300 cc.	Exs. 182, 260	1 †
Pill vials with corks, 4-drachm	4	4
Solid glass rod, 8-inch	4	2
Glass, plain white window glass, 4 × 4 in.	2	2
Glass, red, 4 × 4 in.	Ex. 258	1
Ground glass, 4 × 4 in.	Ex. 250	1
Plate glass, 3 × 4 in.	Ex. 243	1
Boyle's law tube	Ex. 75	1 †
Concave mirror	3	1
Plane mirror	3	1
Kerosene lamp	7	2
Convex lens	10	3
Glass prism	2	1
Glass alcohol lamp, 4-ounce	30	10 *
Bunsen burner	30	10 *
Rubber tubing for Bunsen burners		30 ft. *
Fish-tail burner		1 *
Saucer (common)	5	5
Saucepan, 300 cc.	5	4
Rubber stopper, 2-hole, 28 mm. small diam.	10	4
Rubber stopper, 1-hole, 23 mm. small diam.	7	4
Rubber stopper, solid, 23 mm. small diam.	Exs. 217, 260	1 †
Soft rubber tubing, to fit 6-mm. glass tubing	12	15 ft.
Sheet rubber, 2 × 3 ft.	3	1
Cork stopper, 28 mm. diam.	2	2
Cork stopper, 23 mm. diam.	1	1
Hand bicycle pump	2	1
Meter stick, cm. and inches	5	1
Metric ruler, 30 cm. and 1 ft.	6	4
Spring balances, 250 g.	17	4
Spring balances, 1800 g.	2	1
Sensitive platform scales	7	2
Weights, 1, 1 g.; 2, 2 g.; 1, 5 g.; 1, 10 g.; 2, 20 g.	7	1

	A Exs. needing it	B Amount to buy
Weights, iron, with hook, 1, 10 g.; 2, 20 g.; 1, 50 g.; 1, 100 g.; 2, 200 g.; 2, 500 g.	5	1
Weights, iron, one each of 1, 2, 4, and 8-ounce		1 †
Small wooden cone	1	1
Lead bob for pendulum	5	3 †
Support for pendulums	7	1 †
Single pulley	3	1 †
Double movable pulley	3	1 †
Wheel and axle	Ex. 150	1 †
Adjustable inclined plane	Ex. 155	1 †
Ring stand, 2 rings	12	3
Tripod, iron	6	4
Clamp for ring stand	3	1
Rotating device	2	1 †
Sonometer	3	1 †
Vibration-rate apparatus	Ex. 224	1 †
Adjustable organ pipe	Ex. 231	1 †
Gold leaf or aluminium leaf	Ex. 260	1
Stick sealing wax, 8-inch	3	1
Sealing wax, 1 lb.	Ex. 266	1
Cat's fur	Ex. 266	1 †
Static electric machine	Ex. 267	1 †
Leyden jar	Ex. 267	1 †
Compass	14	5
Magnetized needle, open, on pivot	Ex. 303	1
Porous cup	Ex. 271	1
Cell (dry battery)	22	12
Electric bell	3	1
Voltmeter	Ex. 274	1 †
Induction coil	Ex. 283	1 †
Electro-magnet	3	1
Electro-magnet, small	Ex. 307	1
Bar magnet, 6-inch	5	2
Horseshoe magnet, small	4	3
Sheet copper, 3 × 12 inches		1
Sheet zinc, 3 × 6 inches		1
No. 22 insulated copper wire, spool		1
No. 26 insulated copper wire, 50 feet	Ex. 301	1
No. 30 insulated copper wire, 20 feet	2	1
No. 30 iron wire	5	25 ft.
No. 10 iron wire	3	3 ft.

	A Exs. needing it	B Amount to buy
No. 12 iron wire	7	100 ft.
No. 16 copper wire	1	2 ft.
No. 10 copper wire	1	1 ft.
No. 10 brass wire	2	1 ft.
Iron filings	8	1 lb.
Sulphuric acid, commercial	7	2 lb. ‡
Muriatic acid, commercial	Ex. 163	2 oz. ‡
Zinc	Ex. 163	1 oz. ‡
Lime	Ex. 162	1 oz. ‡
Copper sulphate	2	8 oz. ‡
Ammonium nitrate	Ex. 208	1 lb. ‡
Ammonium chloride	Ex. 208	1 lb. ‡
Mercury, liquid	4	3 lb.
BB shot	3	4 oz.
Saltpeter	1	2 oz. ‡
Roll sulphur	Ex. 24	2 oz. ‡
Carbon bisulphide	Ex. 24	2 oz. ‡
Candles	10	12
Alcohol		1 lb. §

* If gas is available, get the Bunsen burners, tubing, and fish-tail burner; otherwise the alcohol lamps should be bought.

† If these things are omitted or are made by instructor, the cost will be materially lessened.

‡ For a class to use these individually the amounts should be increased at the instructor's discretion.

§ If alcohol lamps are used, the quantity of alcohol should be increased accordingly.

Some other material, including baseballs, rubber balls, tacks, nails, screw eyes, small machine-oil cans, tin pie plates, marbles, pipestems, two hammers, a whisk broom, a saw, a file, needles, a bell, a lampwick, common bottles, leather, cardboard, and like common things, are not included in this list, but may be easily supplied by teacher or students.

There should, of course, be some tools about any laboratory. A triangular file is necessary; also a screw-driver, flat file, knife, pincers, vise, wrench, forceps, scissors, some stout string, screws, staples, and machine oil may be used in connection with the exercises.

ANNOUNCEMENTS

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